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# DIGESTIBLE NUTRIENTS AND METABOLIZABLE ENERGY IN CERTAIN SILAGES, HAYS, AND MIXED RATIONS[1]

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## INTRODUCTION

Investigation of the nutritive value of livestock feeds is a study of perennial importance. The studies herein reported were made to determine the nutritive value of sweetclover-oat straw silage, sweetclover silage, sunflower silage, corn silage, first and second cuttings, of sweetclover hay, sweetclover stems, and wild oats (*Avena fatua* L.). In certain cases the feeds mentioned were supplemented. The corn silage also served as a standard of comparision in comparative feeding trials with groups of steers. All of the tests on sweetclover were on the common white variety (*Melilotus alba* Desr.).

The first digestion trials were made with sheep in the winter and spring of 1923. During the fall and winter seasons of 1923–24 and 1924–25 additional trials were made in which steers were used as experimental animals. The trials with steers included determination of the metabolizable energy in addition to digestibility of the feeds.

## EXPERIMENTAL ANIMALS

Six western grade wethers were secured on the open market for the digestion trials with sheep. They were barn-fed and handled to tame them.

In the cattle-feeding trials of 1923 and 1924, four good long-yearling steers of Shorthorn-Hereford breeding were used. They were about 20 months old at the beginning and about 24 months at the end of the tests. They had been used the previous year in a study of the protein requirements of growing cattle and were therefore accustomed to the routine of metabolism trials.

In 1924–25 good steer calves in which Hereford breeding predominated were used. They were about 9 months old when the first test started and about 12 months at the close.

For purposes of identification the letters A to F, inclusive, were used for the sheep; A–22 to D–22 for the steers used in 1923–24, and A–24 to D–24 for the steers used in 1924–25.

## EQUIPMENT AND COLLECTION OF EXCRETA

For the sheep a set of six individual hog-feeding crates were remodelled by equipping them with suitable mangers and 5-pound butter jars for water receptacles. The crates were large enough to permit considerable freedom in getting up and down but did not allow space for turning about.

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[2] The authors acknowledge the assistance of L. L. Nesbitt, assistant agricultural chemist, in making the chemical analyses, and of R. G. Montgomery in feeding and caring for the animals.

Bags for collecting the feces were made from ordinary duck, lined with a high grade of hospital-rubber sheeting. The bags were held in place with a light harness.

The feces were collected from the bags morning and evening and the total for the 24-hour period taken to the chemical laboratory where composite samples for the period were prepared and analyzed.

The feces and urine from the steers were collected by means of rubber ducts and rubber funnels of types long used at the Institute of Animal Nutrition of the Pennsylvania State College. The visible excreta were weighed daily and samples taken to the chemical laboratory for analysis.

## WEIGHING AND SAMPLING OF FEEDS AND EXCRETA

The sheep rations for the entire day were weighed up in the morning and approximately one-half was fed in the morning and the remainder in the evening. It was soon found that individual sheep differed greatly in their likes and dislikes for the silages and hays and also in their capacities for feed consumption. Attempts to feed uniform rations to the sheep on a given feed proved futile, consequently an attempt was made to adjust the rations as nearly as possible to the appetite of the individual sheep. This attempt was only partially successful, as is evidenced by the rations offered and the feed residues collected.

In the trials with steers the dry hays and concentrates were weighed up in advance for the entire trial and samples were taken at that time. The hays were weighed into canvas bags and the concentrates into covered lard cans. When the silages were fed, enough was weighed out for each day and approximately one-half was fed in the morning and the other half in the evening. Samples of the silage were taken daily as the rations were weighed out. All samples were immediately taken to the chemical laboratory for composite sampling and analysis.

In the sheep trials the feeds and feces were weighed to the nearest gram, but in the trials with steers scales with beams graduated in tenths and hundredths of a pound were used and feeds and excreta were weighed to hundredths of a pound.

## METHODS OF CHEMICAL ANALYSIS

The chemical analyses of the feeds, feed residues, and feces for moisture, ash, crude protein (total nitrogen $\times$ 6.25), true protein (albuminoid nitrogen $\times$ 6.25), ether extract, and crude fiber, and analyses of the urines for total nitrogen were made by the official methods of the Association of Official Agricultural Chemists. The total fecal excrement from the sheep trials were air-dried in a bulk-sample drier (*5*) [3] and sampled for analysis after grinding. The fresh urine and fecal samples from the steer trials were preserved with toluene and refrigeration. The fresh steer urine and fecal samples were analyzed daily for nitrogen, and the composites for moisture and nitrogen. The fresh composite fecal samples were dried in the bulk-sample drier for further analysis.

[3] Reference is made by number (italic) to Literature Cited, p. 512.

The energy values were determined with a Parr adiabatic oxygen-bomb calorimeter observing all of the necessary corrections. Before combustion the urines were dried over sulphuric acid in vacuum desiccators, and the calorific values corrected for nitrogen lost on drying.

## METABOLISM TRIALS

The metabolism trials included determinations of digestibility of the rations, and in the experiments with the steers included also nitrogen balances and energy determinations on feeds and visible excreta. The trials were 10 days in length except in some of those of 1924–25 where they were 18 days long with 9-day subperiods (a and b). The preliminary and transitional periods varied in length, but in no case was the preliminary period on the test ration less than 7 days and usually it was 10 days or more. In spite of care in adjusting the test ration to the appetites of the test animals, considerable feed was left uneaten in some of the trials.

To facilitate the general account of the experiments, a schedule including dates of the preliminary and transitional feeding periods, dates of the metabolism periods, the trial numbers, the kind of animals used and their identification letters or numbers, and the kind of rations fed is given in table 1.

TABLE 1.—*Schedule of metabolism trials*

| Group of experiments and trial No. | Animal designation | Feeds | Transitional and preliminary periods [1] | Metabolism periods |
|---|---|---|---|---|
| Experiments of 1922–23 with sheep: | | | | |
| 1 | A, B | Sweetclover-oat straw silage, 1922 | Feb. 10–27 | Feb. 28–Mar. 9. |
| 2 | D, E, F | Sweetclover silage, bud stage, 1922 | do | Do. |
| 3 | A, B, C | Sunflower silage, 1922 | Mar. 11–27 | Mar. 28–Apr. 6. |
| 4 | D, E, F | Corn silage, 1922 | do | Do. |
| 5 | A | Sweetclover hay, first cutting, 1922 | Apr. 7–29 | Apr. 30–May 9. |
| 6 | C, D | Sweetclover hay, second cutting, 1922 | do | Do. |
| 7 | E | Sweetclover stems and corn meal, 1922 | do | Do. |
| Experiments of 1923–24 with steers: | | | | |
| 8 | A–22, B–22 | Sweetclover silage, early bloom, 1923 | Dec. 25–Jan. 15 | Jan. 16–25. |
| 9 | C–22, D–22 | Sweetclover silage, early bloom, 1923, alfalfa, and linseed meal | do | Do. |
| 10 | A–22, B–22 | Sweetclover silage, full bloom, 1923 | Jan. 26–Feb. 5 | Feb. 6–15. |
| 11 | C–22, D–22 | Sweetclover silage, full bloom, 1923, alfalfa, and linseed meal | do | Do. |
| 12 | A–22, B–22 | Sunflower silage, 1923, alfalfa, and linseed meal | Feb. 16–Mar. 11 | Mar. 12–21 |
| 13 | C–22 | Sunflower silage, 1923 | do | Do. |
| 14 | A–22, B–22 | Corn silage, 1923, alfalfa, and linseed meal | Mar. 22–Apr. 1 | Apr. 2–11. |
| 15 | C–22, D–22 | Corn silage, 1923 | do | Do. |
| 16 | A–22, B–22 | Alfalfa hay, 1923 | Apr. 14–29 | Apr. 30–May 9. |
| 17 | C–22, D–22 | Alfalfa hay, 1923, and linseed meal | do | Do. |
| Experiments of 1924–25 with steers: | | | | |
| 18 | A–24, B–24, C–24, D–24 | Alfalfa hay, 1924 | Nov. 12–Dec. 9 | Dec. 10–19. |
| 19 | A–24, B–24, C–24, D–24 | Sweetclover silage, early bloom, 1924, alfalfa, barley, and linseed meal | Dec. 20–Feb. 8 | Feb. 9–26.[2] |
| 20 | A–24, B–24, C–24, D–24 | Sweetclover silage, early bloom, 1924 | Feb. 27–Mar. 15 | Mar. 16–Apr. 2.[2] |
| 21 | A–24, B–24 | Wild oats, alfalfa hay | Apr. 3–May 2 | May 3–22.[3] |
| 22 | C–24, D–24 | Alfalfa hay | do | Do. |

[1] Dates are inclusive.
[2] These 18-day periods were divided into subperiods of 9 days each.
[3] This 20-day period was divided into subperiods of 10 days each.

## DESCRIPTION OF FEEDS

The same general method was used each year in preparing the silage. The crops were chopped with the usual equipment and thoroughly packed in 25-ton concrete stave silos. About every other day for a week or 10 days after filling, water was sprinkled over the silage, and the material thoroughly packed at the top by tamping. The sweetclover was cut with a binder, leaving a stubble 8 to 10 inches high.

One year the inside of the silos was coated with paraffin in an experiment to determine whether or not this treatment would make it easier to remove the frozen silage from the walls. There was no apparent advantage from this treatment. Paraffin was also used for sealing the doors and the top of the silo. Sealing the doors with paraffin proved helpful in preventing spoilage around the doors of the experimental silos and it has been used regularly in later years. For sealing the silage at the top the paraffin proved unsatisfactory. Cracks formed in the paraffin as the silage settled and about the usual amount of spoilage occurred.

### SWEETCLOVER-OAT STRAW SILAGE (BUD STAGE)

The sweetclover for the sweetclover-oat straw silage fed in trial 1 was cut in the bud stage, when the plants were about 36 inches high. The freshly cut material as ensiled contained 17.6 percent of dry matter. The water content was reduced by adding, as the sweetclover was chopped, 1 part of dry oat (*Avena sativa* L.) straw to 5.5 parts of sweetclover. Considerable difficulty was experienced in obtaining a uniform mixture of the wet sweetclover and the dry oat straw, resulting in some moldy spots found occasionally throughout the silo. These moldy portions were discarded so far as possible in feeding.

### SWEETCLOVER SILAGE (BUD STAGE)

The silage made from sweetclover cut in the bud stage of growth was fed in trial 2. The moisture content was reduced by wilting and the material as ensiled contained 34.8 percent of dry matter. Unfavorable weather conditions delayed ensiling 14 days after cutting. The bundles were shocked and the sweetclover was in good condition in spite of the adverse weather conditions.

### SWEETCLOVER SILAGE (EARLY BLOOM STAGE)

The sweetclover silage of 1923, fed in trials 8 and 9, was made from sweetclover cut when the plants were 5 to 10 percent in blossom. The sweetclover was allowed to wilt in the field and when ensiled the material contained 33.9 percent of dry matter.

The sweetclover for the 1924 early bloom stage of growth silage, which was fed in trials 19 and 20, was allowed to wilt in the field until the leaves on the outer portion of the bundles were either dried or very much wilted and the stems considerably shrunken. Rain delayed ensiling. The first portion ensiled contained 22.1 percent and the second 26.5 percent of dry matter. The resulting silage was well-preserved, having an olive-green color and a strong sweetclover odor. In appearance and palatability it was better than the other sweetclover silages.

### SWEETCLOVER SILAGE (FULL BLOOM STAGE)

The sweetclover for the silage of 1924, which was fed in trials 10 and 11, was cut in full bloom and allowed to wilt in the field. When ensiled, it contained 42.8 percent of dry matter.

### SUNFLOWER SILAGE

The Mammoth Russian sunflowers (*Helianthus annuvus* L.) for the silage made in 1922 and fed in trial 3 were cut when a count showed 85 percent of the plants were in blossom, 3 percent had dropped their petals, and 12 percent were in bud. The material as ensiled contained 21.4 percent of dry matter.

The Mammoth Russian sunflowers for the silage made in 1923 and fed in trials 12 and 13 were cut immediately after a killing frost when 75 percent of the plants had reached or passed the blossom stage of growth. Rain delayed ensiling until the third and sixth days after cutting. The leaves were all well-dried or rusted when the plants were cut, and moldy spots were noted on some of the coarse, woody stalks at the time of ensiling. The material when ensiled contained 31.8 percent of dry matter.

### CORN SILAGE

The Mercer flint corn (*Zea mays* L.) for the silage made in 1922 and fed in trial 4 was cut in the late milk to early dough stage of growth. The plants were from 7 to 9 feet high and were ensiled without much wilting. The ears represented 40 percent and the stover 60 percent of the dry matter in the fodder. As ensiled the fodder contained 24.7 percent of dry matter.

The Mercer flint corn for the silage made in 1923 and fed in trials 14 and 15 was cut in the glazed stage of growth and as ensiled contained 38.1 percent of dry matter.

### SWEETCLOVER HAY AND STEMS

The sweetclover hays from the first cutting (trial 5) and from the second cutting (trial 6) were cut in the early blossom stage of growth. The hays were ground in a hammer mill, through a hay screen, reducing the leaves largely to a powder and the stems to particles one-half inch or less in length. The hays were both good, but a little coarse-stemmed.

The sweetclover stems were those left after sheep had eaten practically all of the leaves and fine stems from hay cut in the early blossom stage of growth. The stems were ground in the hammer mill and fed to two sheep in a digestion trial (7), but only one sheep ate enough to complete the trial period, even when supplemented with corn.

### ALFALFA HAY

The alfalfa hay for the 1923–24 trials (9, 11, 12, 14, 16, and 17) was of fairly good quality but was rather coarse-stemmed with a fair amount of leaves but somewhat lacking in color.

The alfalfa (*Medicago sativa* L.) for the 1924–25 trials (18, 19, 21, and 22) was somewhat better, being leafier, finer-stemmed and having a better color.

### CONCENTRATES

The linseed meal was the standard old-process product.

The barley (*Hordeum vulgare* L.) (trial 19) and corn meal (trial 7) were of good feed grade.

The wild oats [4] (fed in trial 21), which are removed in cleaning wheat for milling and commonly ground and sold as "mill oats," were found on analysis [5] to consist of 84.4 percent of wild oats, mostly dark color, 9.2 percent of cultivated oats, 4.9 percent of wheat (*Triticum aestivum* L.), 1.5 percent of barley, and a trace of rye (*Secale cereale* L.). They had a test weight of 37.5 pounds per bushel and a separation showed 65 percent of kernel and 35 percent of hulls by weight.

## COMPOSITION OF CROPS AND FEEDS

The chemical composition of each of the green silage crops and the resulting silages, and of the alfalfa hay, sweetclover hay, sweetclover stems, and concentrates is given in table 2. The trial in which the feeds were fed is indicated by the trial number.

[4] The wild oats were from the same lot as those fed by Griswold ((4), *p. 12*).
[5] Analysis by P. J. Olson, assistant agronomist, North Dakota Agricultural Experiment Station.

TABLE 2.—*Chemical composition of the green silage crops and the resulting silages, and of the alfalfa and sweetclover hays, the sweetclover stems, and the concentrates fed*

| Hay, feed, or silage | Year or trial No. | Dry matter | Composition of dry matter | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ash | Crude protein | Crude fiber | N-free extract | Ether extract | Energy per 100 pounds | Protein nitrogen | Non-protein nitrogen |
| | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Therms* | *Percent* | *Percent* |
| Crops when ensiled: | | | | | | | | | | |
| Sweetclover-oat straw: | | | | | | | | | | |
| Sweetclover, bud stage | 1922 | 17.59 | 9.91 | 19.90 | 25.75 | 42.55 | 1.91 | | | |
| Oat straw | 1922 | 83.90 | 8.88 | 6.34 | 40.58 | 42.03 | 2.17 | | | |
| Sweetclover, bud stage | 1922 | 34.75 | 9.16 | 21.21 | 29.60 | 38.02 | 2.01 | | | |
| Sweetclover, early bloom | 1923 | 33.91 | 8.91 | 17.64 | 32.76 | 38.73 | 1.96 | | 1.886 | 0.937 |
| Sweetclover, full bloom | 1923 | 42.77 | 8.86 | 19.62 | 33.54 | 35.84 | 2.14 | | 1.920 | 1.219 |
| Sweetclover, early bloom, silo 1 | 1924 | 22.12 | 10.41 | 22.31 | 29.08 | 35.40 | 2.80 | | 2.132 | 1.437 |
| Sweetclover, early bloom, silo 2 | 1924 | 26.45 | 9.65 | 21.13 | 29.42 | 36.72 | 3.08 | | 1.836 | 1.545 |
| Average | | 24.29 | 10.03 | 21.72 | 29.25 | 36.06 | 2.94 | | 1.984 | 1.491 |
| Sunflowers | 1922 | 21.40 | 9.88 | 9.34 | 30.30 | 49.02 | 1.46 | | | |
| Corn fodder, green | 1923 | 31.80 | 12.68 | 9.62 | 33.33 | 42.14 | 2.23 | | 1.150 | .389 |
| | 1922 | 24.71 | 7.62 | 8.36 | 20.82 | 61.01 | 2.19 | | | |
| | 1923 | 38.07 | 5.09 | 8.10 | 16.82 | 67.00 | 2.99 | | 1.117 | .179 |
| Silages: | | | | | | | | | | |
| Sweetclover-oat straw | 1 | 21.97 | 10.96 | 14.16 | 41.22 | 29.05 | 4.61 | | | |
| Sweetclover, bud stage (1922) | 2 | 34.78 | 9.70 | 21.53 | 35.71 | 29.76 | 3.30 | | | |
| Sweetclover, early bloom (1923) | 8 and 9 | 33.47 | 9.21 | 18.33 | 29.91 | 39.47 | 3.09 | 212.14 | 1.012 | 1.921 |
| Sweetclover, full bloom (1923) | 10 and 11 | 32.66 | 9.95 | 21.36 | 32.00 | 33.97 | 2.72 | 210.16 | 1.350 | 2.067 |
| Sweetclover, early bloom, subperiod a, 1924 | 19 | 23.84 | 10.24 | 20.72 | 33.57 | 31.96 | 3.51 | 209.68 | 1.077 | 2.238 |
| Sweetclover, early bloom, subperiod b, 1924 | 19 | 24.21 | 10.22 | 21.24 | 32.40 | 32.64 | 3.50 | 207.61 | 1.043 | 2.356 |
| Average | | 24.02 | 10.23 | 20.98 | 32.98 | 32.30 | 3.50 | 208.64 | 1.060 | 2.297 |
| Sweetclover, early bloom, subperiod a, 1924 | 20 | 24.85 | 9.98 | 22.47 | 31.02 | 32.74 | 3.79 | 211.55 | 1.541 | 2.054 |
| Sweetclover, early bloom, subperiod b, 1924 | 20 | 24.55 | 10.09 | 22.44 | 31.28 | 32.34 | 3.85 | 212.30 | 1.565 | 2.026 |
| Average | | 24.70 | 10.04 | 22.46 | 31.15 | 32.54 | 3.82 | 211.92 | 1.553 | 2.040 |
| Average of all sweetclover | | 28.34 | 9.91 | 21.16 | 32.27 | 33.27 | 3.39 | 210.57 | 1.265 | 2.110 |
| Sunflowers (1922) | 3 | 26.18 | 9.95 | 10.20 | 32.58 | 44.49 | 2.78 | | | |
| Sunflowers (1923) | 12 and 13 | 26.05 | 15.00 | 8.20 | 38.15 | 35.55 | 2.10 | 188.29 | .797 | .515 |
| Average | | 26.12 | 12.48 | 9.20 | 35.37 | 40.52 | 2.44 | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Corn (1922) | 4 | 24.35 | 7.86 | 10.16 | 22.89 | 56.36 | 2.73 | | | |
| Corn (1923) | 14 and 15 | 30.47 | 7.09 | 8.29 | 22.48 | 59.36 | 2.78 | 201.66 | .786 | .540 |
| Average | | 27.41 | 7.48 | 9.23 | 22.69 | 57.86 | 2.76 | | | |
| Alfalfa hay | 9 | 84.72 | 10.62 | 15.98 | 34.64 | 37.15 | 1.61 | 199.72 | 1.896 | .660 |
| | 11 | 83.78 | 10.55 | 16.54 | 35.41 | 35.85 | 1.65 | 199.66 | 1.917 | .730 |
| | 12 | 86.02 | 10.25 | 16.19 | 35.66 | 36.45 | 1.45 | 197.88 | 1.885 | .706 |
| | 14 | 86.40 | 9.44 | 14.98 | 39.03 | 35.17 | 1.38 | 199.53 | 1.724 | .673 |
| | 16 and 17 | 85.59 | 10.40 | 16.68 | 35.62 | 36.05 | 1.25 | 200.50 | 1.922 | .747 |
| | 18 | 84.81 | 9.90 | 17.16 | 32.18 | 38.48 | 2.28 | 199.74 | 2.183 | .563 |
| | 19 | 84.49 | 9.71 | 17.38 | 32.05 | 38.57 | 2.29 | 202.65 | 2.166 | .615 |
| | 21 and 22 | 85.34 | 9.49 | 16.79 | 33.91 | 37.98 | 1.83 | 201.92 | 2.119 | .568 |
| Sweetclover hay, first cutting, ground | 5 | 82.46 | 10.50 | 16.27 | 38.82 | 32.65 | 1.76 | | | |
| Sweetclover hay, second cutting, ground | 6 | 82.58 | 7.36 | 18.46 | 36.15 | 36.30 | 1.73 | | | |
| Sweetclover stems, ground | 7 | 85.33 | 6.28 | 9.42 | 52.29 | 31.04 | .97 | | | |
| Composition of concentrates fed with hays and silages: | | | | | | | | | | |
| Corn meal | 7 | 85.54 | 2.04 | 10.90 | 3.50 | 79.67 | 3.89 | | | |
| Linseed meal | 9 | 88.76 | 6.73 | 39.01 | 9.37 | 37.50 | 7.39 | 222.73 | 5.870 | .371 |
| | 11 | 88.55 | 6.74 | 39.48 | 9.31 | 37.01 | 7.46 | 221.72 | 5.759 | .557 |
| | 12 | 88.04 | 6.76 | 39.86 | 9.43 | 36.74 | 7.21 | 223.24 | 5.946 | .432 |
| | 14 | 88.51 | 6.82 | 39.64 | 9.06 | 37.63 | 6.85 | 223.88 | 5.729 | .613 |
| | 17 | 88.57 | 6.65 | 39.66 | 9.63 | 37.17 | 6.89 | 224.39 | 5.656 | .690 |
| | 19 | 85.87 | 5.42 | 37.49 | 9.61 | 40.94 | 6.54 | | 5.713 | .285 |
| Barley, ground | 19 | 85.96 | 3.41 | 12.47 | 5.81 | 76.06 | 2.25 | | 1.915 | .080 |
| Grain mixture, (ground barley 3 parts, linseed meal 1 part) | 19 | 86.65 | 3.98 | 19.33 | 7.42 | 66.17 | 3.10 | 206.81 | 2.892 | .201 |
| Wild oats | 21 | 88.07 | 4.41 | 13.30 | 15.50 | 60.77 | 6.02 | 214.03 | 1.893 | .235 |

It is not possible to make close comparisons between the composition of the crop as it was ensiled and the resulting silage because the samples of the crops were taken to represent the material as it was put into the silo, either as a whole or as definite portions of the whole. The samples taken for the digestion trials represent only the silage fed during the trials, and, consequently, they represent a rather limited portion of the whole. An inspection of the data, however, shows some outstanding differences.

The dry-matter content of the crops as compared to the silages varied considerably in some years and very little in others. These variations probably resulted chiefly from differences in the quantities of water added at the top of the silos in packing the material and from leakages at the bottom. A comparison of the composition of the dry matter indicates that, in general, the ash was lower in the crop than in the silage. Similarly, the protein was usually lower in the crop than in the silage, excepting the sunflowers of 1923 where the protein was 1.42 percent higher in the crop than in the silage. With the exception mentioned, the protein ranged from 0.19 to 1.80 percent lower in the crop than in the silage. The crude fiber in the sweetclover of 1923 was 1.54 to 2.85 percent higher in the crop than in the silage, but in all of the other silages the crude fiber ranged from 0.21 to 6.11 percent lower in the crop than in the silage. The nitrogen-free extract ranged from 1.87 to 8.26 percent higher in the crop than in the silage, except in the early cutting of sweetclover, 1923, which showed 0.74 percent less in the crop. The ether extract in the silage ranged from 0.54 to 1.32 percent higher than the crop, except in the sunflower silage, 1923, and the corn silage, 1923, where it was 0.13 and 0.21 percent lower, respectively.

A comparison of the average composition of seven samples of sweetclover silage with the average of two samples of corn silage shows that the sweetclover silages contained 2.43 percent more ash, 11.93 percent more crude protein, 9.58 percent more crude fiber and 0.63 percent more ether extract, but 24.59 percent less of nitrogen-free extract.

A similar comparison of the average of two sunflower silages with the two corn silages shows that the sunflower silage contained nearly the same amounts of protein and nonprotein nitrogen and ether extract as the corn silage, but it contained 5.00 percent more ash and 12.68 percent more crude fiber and 17.34 percent less of nitrogen-free extract. The sunflower silages averaged 3.1 percent higher in crude fiber than the sweetclover silages.

### PROTEIN NITROGEN IN PERCENT OF TOTAL NITROGEN IN CROPS AND IN SILAGES

Determinations of protein and nonprotein nitrogen made on a number of the crops and silages show that considerable amounts of protein were broken down into the nonprotein form. The extent of these changes is shown in table 3. In this table the protein nitrogen is given in percentage of the total. The protein nitrogen in the crops ranged from 57.02 to 86.19 percent of the total nitrogen. In the silages the protein nitrogen ranged from 34.50 to 60.75 percent. The changes from protein to nonprotein nitrogen ranged from 13.97 percent in the sunflowers to 32.31 percent in the early bloom sweetclover of 1923.

TABLE 3.—*Protein nitrogen as percentage of total nitrogen in crops and in silages*

| Kind of crop | Crop | | Silage | | Difference |
|---|---|---|---|---|---|
| | Year | Percent | Trial No. | Percent | |
| | | | | | *Percent* |
| Sweetclover, early bloom | 1923 | 66.81 | 1–23 | 34.50 | 32.31 |
| Sweetclover, full bloom | 1923 | 61.17 | 2–23 | 39.51 | 21.66 |
| Sweetclover, early bloom | 1924 | [1] 57.02 | 3–24 | [2] 37.41 | 19.61 |
| Sunflower | 1923 | [1] 74.72 | 3–23 | 60.75 | 13.97 |
| Corn fodder, green | 1923 | 86.19 | 4–23 | 59.28 | 26.91 |

[1] Average of 2 analyses.
[2] Average of 4 analyses.

## DIGESTIBILITY OF THE SILAGES

The rations fed, feed residues and feces collected, and the detailed data on the digestibility of the nutrients in the silages are given in table 4. Data showing the composition of the feed residues and feces in the trials are omitted. Their composition, if desired, can readily be computed from the tables on digestibility. The data on the digestibility of other feeds and rations are given in succeeding tables. The digestion coefficients determined in the trials are summarized in table 7 and a discussion of the results appears in connection with it.

TABLE 4.—*Digestibility of sweetclover-oat straw silage, sweetclover silage, sunflower silage, corn silage, alfalfa and sweetclover hays, and sweetclover stems, when fed to sheep and steers*

| Trial No. | Animal | Feeds and other items | Original weight | Dry matter | Organic matter | Ash | Crude protein | Crude fiber | N-free extract | Ether extract |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Sweetclover-oat straw silage: | | | | | | | | |
| | | Silage, bud stage ..... grams | 1,585.0 | 348.2 | 310.0 | 38.2 | 49.3 | 143.5 | 101.2 | 16.1 |
| | | Feed residue ..... do | 81.2 | 74.9 | 67.5 | 7.4 | 9.5 | 28.3 | 28.0 | 1.7 |
| 1 | Sheep A | Total eaten ..... do | | 273.3 | 242.5 | 30.8 | 39.8 | 115.2 | 73.2 | 14.4 |
| | | Feces ..... do | 445.5 | 188.4 | 165.2 | 23.2 | 19.4 | 71.4 | 68.6 | 5.8 |
| | | Digested ..... do | | 84.9 | 77.3 | 7.6 | 20.4 | 43.8 | 4.6 | 8.6 |
| | | do ..... percent | | 31.06 | 31.88 | 24.68 | 51.26 | 38.02 | 6.28 | 59.72 |
| | | Silage, bud stage ..... grams | 1,133.0 | 248.9 | 221.6 | 27.3 | 35.2 | 102.6 | 72.3 | 11.5 |
| | | Feed residue ..... do | 12.7 | 12.0 | 10.8 | 1.2 | 1.2 | 4.9 | 4.4 | .2 |
| 1 | Sheep B | Total eaten ..... do | | 236.9 | 210.8 | 26.1 | 34.0 | 97.7 | 67.9 | 11.3 |
| | | Feces ..... do | 324.2 | 148.7 | 129.2 | 19.5 | 16.4 | 52.8 | 54.5 | 5.6 |
| | | Digested ..... do | | 88.2 | 81.6 | 6.6 | 17.6 | 44.9 | 13.4 | 5.7 |
| | | do ..... percent | | 37.23 | 38.71 | 25.29 | 51.76 | 45.96 | 19.73 | 50.44 |
| | | Sweetclover silage: | | | | | | | | |
| | | Silage, bud stage ..... grams | 680.0 | 236.5 | 213.6 | 22.9 | 50.9 | 84.5 | 70.4 | 7.8 |
| | | Feed residue ..... do | 128.5 | 120.3 | 109.8 | 10.5 | 24.0 | 48.4 | 35.4 | 1.9 |
| 2 | Sheep D | Total eaten ..... do | | 116.2 | 103.8 | 12.4 | 26.9 | 36.1 | 35.0 | 5.9 |
| | | Feces ..... do | 160.1 | 58.1 | 52.5 | 5.6 | 7.3 | 27.6 | 15.5 | 2.1 |
| | | Digested ..... do | | 58.1 | 51.3 | 6.8 | 19.6 | 8.5 | 19.5 | 3.8 |
| | | do ..... percent | | 50.00 | 49.42 | 54.84 | 72.86 | 23.55 | 55.71 | 64.41 |
| | | Silage, bud stage ..... grams | 1,586.0 | 551.6 | 498.1 | 53.5 | 118.8 | 197.0 | 164.2 | 18.2 |
| | | Feed residue ..... do | 12.7 | 11.9 | 10.9 | 1.0 | 2.0 | 5.4 | 3.4 | .1 |
| 2 | Sheep E | Total eaten ..... do | | 539.7 | 487.2 | 52.5 | 116.8 | 191.6 | 160.8 | 18.1 |
| | | Feces ..... do | 697.7 | 225.4 | 205.2 | 20.2 | 26.3 | 106.1 | 66.0 | 6.8 |
| | | Digested ..... do | | 314.3 | 282.0 | 32.3 | 90.5 | 85.5 | 94.8 | 11.3 |
| | | do ..... percent | | 58.24 | 57.88 | 61.52 | 77.48 | 44.62 | 58.96 | 62.43 |
| | | Silage, bud stage ..... grams | 680.0 | 236.5 | 213.6 | 22.9 | 50.9 | 84.5 | 70.4 | 7.8 |
| | | Feed residue ..... do | 67.4 | 63.5 | 58.0 | 5.5 | 10.9 | 26.9 | 19.6 | .6 |
| 2 | Sheep F | Total eaten ..... do | | 173.0 | 155.6 | 17.4 | 40.0 | 57.6 | 50.8 | 7.2 |
| | | Feces ..... do | 198.9 | 73.8 | 66.2 | 7.6 | 9.1 | 32.4 | 22.1 | 2.7 |
| | | Digested ..... do | | 99.2 | 89.4 | 9.8 | 30.9 | 25.2 | 28.7 | 4.5 |
| | | do ..... percent | | 57.34 | 57.46 | 56.32 | 77.25 | 43.75 | 56.50 | 62.50 |
| | | Silage, early bloom ..... pounds | 40.000 | 13.388 | 12.156 | 1.232 | 2.454 | 4.004 | 5.284 | .414 |
| | | Feed residue ..... do | [1].018 | .016 | .014 | .002 | .003 | .006 | .005 | .000 |
| 8 | Steer A–22 | Total eaten ..... do | 39.982 | 13.372 | 12.142 | 1.230 | 2.451 | 3.998 | 5.279 | .414 |
| | | Feces ..... do | 26.999 | 5.478 | 4.996 | .482 | .721 | 2.485 | 1.614 | .176 |
| | | Digested ..... do | | 7.894 | 7.146 | .748 | 1.730 | 1.513 | 3.665 | .238 |
| | | do ..... percent | | 59.02 | 58.85 | 60.81 | 70.58 | 37.84 | 69.43 | 57.49 |
| | | Silage, early bloom ..... pounds | 40.000 | 13.388 | 12.156 | 1.232 | 2.454 | 4.004 | 5.284 | .414 |
| | | Feed residue ..... do | [1].009 | .018 | .016 | .002 | .003 | .007 | .006 | .001 |
| 8 | Steer B–22 | Total eaten ..... do | 39.991 | 13.370 | 12.140 | 1.230 | 2.451 | 3.997 | 5.278 | .413 |
| | | Feces ..... do | 28.654 | 5.565 | 5.047 | .518 | .767 | 2.456 | 1.658 | .166 |
| | | Digested ..... do | | 7.805 | 7.093 | .712 | 1.684 | 1.541 | 3.820 | .247 |
| | | do ..... percent | | 58.38 | 58.43 | 57.89 | 68.71 | 38.55 | 68.59 | 59.84 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Steer A-22 | Silage, full bloom—pounds | 40.000 | 13.064 | 11.764 | 1.300 | 2.790 | 4.180 | 4.438 | .355 |
| | | Feed residue—do | [1].645 | .580 | .522 | .058 | .130 | .206 | .171 | .015 |
| | | Total eaten—do | 39.354 | 12.484 | 11.242 | 1.242 | 2.660 | 3.974 | 4.267 | .340 |
| | | Feces—do | 23.805 | 4.759 | 4.314 | .445 | .672 | 2.166 | 1.316 | .160 |
| | | Digested—do | | 7.725 | 6.928 | .797 | 1.998 | 1.808 | 2.951 | .180 |
| | | ——do—percent | | 61.88 | 61.63 | 64.17 | 74.74 | 45.50 | 69.16 | 52.94 |
| 10 | Steer B-22 | Silage, full bloom—pounds | 40.000 | 13.064 | 11.764 | 1.300 | 2.791 | 4.181 | 4.438 | .355 |
| | | Feces—do | 29.988 | 5.455 | 4.963 | .492 | .785 | 2.446 | 1.534 | .197 |
| | | Digested—do | | 7.609 | 6.801 | .808 | 2.005 | 1.734 | 2.904 | .158 |
| | | ——do—percent | | 58.24 | 57.81 | 62.15 | 71.86 | 41.48 | 65.43 | 44.51 |
| 20, subperiod *a* | Steer A-24 | Silage, early bloom—pounds | 26.000 | 6.461 | 5.816 | .645 | 1.452 | 2.004 | 2.115 | .245 |
| | | Feces—do | 13.909 | 2.356 | 2.107 | .249 | .292 | 1.173 | .556 | .086 |
| | | Digested—do | | 4.105 | 3.709 | .396 | 1.160 | .831 | 1.559 | .159 |
| | | ——do—percent | | 63.54 | 63.77 | 61.40 | 79.89 | 41.47 | 73.71 | 64.90 |
| 20, subperiod *b* | Steer A-24 | Silage, early bloom—pounds | 26.000 | 6.383 | 5.739 | .644 | 1.432 | 1.997 | 2.064 | .246 |
| | | Feces—do | 13.910 | 2.316 | 2.051 | .265 | .294 | 1.122 | .551 | .084 |
| | | Digested—do | | 4.067 | 3.688 | .379 | 1.138 | .875 | 1.513 | .162 |
| | | ——do—percent | | 63.72 | 64.26 | 58.85 | 79.47 | 43.82 | 73.30 | 65.85 |
| 20, subperiod *a* | Steer B-24 | Silage, early bloom—pounds | 26.000 | 6.461 | 5.816 | .645 | 1.452 | 2.004 | 2.115 | .245 |
| | | Feces—do | 12.991 | 2.316 | 2.089 | .227 | .289 | 1.166 | 5.42 | .092 |
| | | Digested—do | | 4.145 | 3.727 | .418 | 1.163 | .838 | 1.573 | .153 |
| | | ——do—percent | | 64.15 | 64.08 | 64.81 | 80.10 | 41.82 | 74.37 | 62.45 |
| 20, subperiod *b* | Steer B-24 | Silage, early bloom—pounds | 26.000 | 6.383 | 5.739 | .644 | 1.432 | 1.997 | 2.064 | .246 |
| | | Feces—do | 12.582 | 2.294 | 2.033 | .260 | .301 | 1.113 | .549 | .071 |
| | | Digested—do | | 4.089 | 3.706 | .384 | 1.131 | .884 | 1.515 | .175 |
| | | ——do—percent | | 64.06 | 64.58 | 59.63 | 78.98 | 44.26 | 73.40 | 71.14 |
| 20, subperiod *a* | Steer C-24 | Silage, early bloom—pounds | 28.000 | 6.958 | 6.264 | .694 | 1.564 | 2.158 | 2.278 | .264 |
| | | Feces—do | 17.296 | 2.518 | 2.267 | .251 | .321 | 1.249 | .609 | .088 |
| | | Digested—do | | 4.440 | 3.997 | .443 | 1.243 | .909 | 1.669 | .176 |
| | | ——do—percent | | 63.81 | 63.81 | 63.83 | 79.48 | 42.12 | 73.27 | 66.67 |
| 20, subperiod *b* | Steer C-24 | Silage, early bloom—pounds | 28.000 | 6.874 | 6.180 | .694 | 1.543 | 2.150 | 2.223 | .265 |
| | | Feces—do | 16.240 | 2.509 | 2.237 | .272 | .318 | 1.201 | .628 | .090 |
| | | Digested—do | | 4.365 | 3.943 | 4.22 | 1.225 | .949 | 1.595 | .175 |
| | | ——do—percent | | 63.50 | 63.80 | 60.81 | 79.39 | 44.14 | 71.75 | 66.04 |
| 20, subperiod *a* | Steer D-24 | Silage, early bloom—pounds | 28.000 | 6.958 | 6.264 | .694 | 1.564 | 2.158 | 2.278 | .264 |
| | | Feces—do | 15.507 | 2.571 | 2.312 | 2.60 | 3.22 | 1.272 | .629 | .088 |
| | | Digested—do | | 4.387 | 3.952 | .434 | 1.242 | .886 | 1.649 | .176 |
| | | ——do—percent | | 63.05 | 63.09 | 62.54 | 79.42 | 41.06 | 72.39 | 66.67 |
| 20, subperiod *b* | Steer D-24 | Silage, early bloom—pounds | 28.000 | 6.874 | 6.180 | .694 | 1.543 | 2.150 | 2.223 | .265 |
| | | Feces—do | 14.551 | 2.468 | 21.83 | .285 | .312 | 1.204 | .578 | .089 |
| | | Digested—do | | 4.406 | 3.997 | .409 | 1.231 | .946 | 1.645 | .176 |
| | | ——do—percent | | 64.10 | 64.68 | 58.93 | 79.78 | 44.00 | 74.00 | 66.42 |
| | | Sunflower silage: | | | | | | | | |
| 3 | Sheep A | Silage—grams | 2,500.0 | 654.5 | 589.4 | 65.1 | 66.8 | 213.2 | 291.2 | 18.2 |
| | | Feed residue—do | [1]213.0 | 198.9 | 182.8 | 16.1 | 12.5 | 95.7 | 72.1 | 2.6 |
| | | Total eaten—do | | 455.6 | 406.6 | 49.0 | 54.3 | 117.5 | 219.1 | 15.6 |
| | | Feces—do | [1]232.0 | 207.3 | 182.0 | 25.3 | 25.2 | 70.6 | 81.2 | 4.9 |
| | | Digested—do | | 248.3 | 224.6 | 23.7 | 29.1 | 46.9 | 137.9 | 10.7 |
| | | ——do—percent | | 54.50 | 55.24 | 48.37 | 53.59 | 39.91 | 62.94 | 68.59 |

TABLE 4.—*Digestibility of sweetclover-oat straw silage, sweetclover silage, sunflower silage, corn silage, alfalfa and sweetclover hays, and sweetclover stems, when fed to sheep and steers*—Continued

| Trial No. | Animal | Feeds and other items | Original weight | Dry matter | Organic matter | Ash | Crude protein | Crude fiber | N-free extract | Ether extract |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Sunflower silage—Continued. | | | | | | | | |
| | | Silage.....grams.. | 1,815.0 | 475.2 | 427.9 | 47.3 | 48.5 | 154.8 | 211.4 | 13.2 |
| | | Feed residue.....do.... | [1] 117.1 | 108.9 | 98.6 | 10.3 | 9.5 | 41.9 | 44.7 | 2.5 |
| | | Total eaten.....do.... | | 366.3 | 329.3 | 37.0 | 39.0 | 112.9 | 166.7 | 10.7 |
| 3 | Sheep B | Feces.....do.... | [1] 205.0 | 183.7 | 163.1 | 20.6 | 21.1 | 66.8 | 71.3 | 3.9 |
| | | Digested.....do.... | | 182.6 | 166.2 | 16.4 | 17.9 | 46.1 | 95.4 | 6.8 |
| | | .....do.....percent.. | | 49.85 | 50.47 | 44.32 | 45.90 | 40.83 | 57.23 | 63.55 |
| | | Silage.....grams.. | 1,815.0 | 475.2 | 427.9 | 47.3 | 48.5 | 154.8 | 211.4 | 13.2 |
| | | Feed residue.....do.... | [1] 69.4 | 64.5 | 58.2 | 6.3 | 5.8 | 26.9 | 24.2 | 1.4 |
| | | Total eaten.....do.... | | 410.7 | 369.7 | 41.0 | 42.7 | 127.9 | 187.2 | 11.8 |
| 3 | Sheep C | Feces.....do.... | [1] 217.3 | 194.6 | 172.9 | 21.7 | 20.2 | 70.6 | 77.9 | 4.2 |
| | | Digested.....do.... | | 216.1 | 196.8 | 19.3 | 22.5 | 57.3 | 109.3 | 7.6 |
| | | .....do.....percent.. | | 52.62 | 53.23 | 47.07 | 52.69 | 44.80 | 58.39 | 64.41 |
| | | Silage.....pounds.. | 24.000 | 6.252 | 5.314 | .938 | .513 | 2.385 | 2.285 | .131 |
| | | Feces.....do.... | 13.766 | 3.125 | 2.738 | .387 | 2.88 | 1.438 | .977 | .036 |
| 13 | Steer C–22 | Digested.....do.... | | 3.127 | 2.576 | .551 | 2.25 | .947 | 1.308 | .095 |
| | | .....do.....percent.. | | 50.02 | 48.48 | 58.74 | 43.86 | 39.71 | 57.24 | 72.52 |
| | | Corn silage: | | | | | | | | |
| | | Silage.....grams.. | 1,815.0 | 442.0 | 407.3 | 34.7 | 44.9 | 101.2 | 249.1 | 12.1 |
| | | Feed residue.....do.... | [1] 95.2 | 89.7 | 80.2 | 9.5 | 7.8 | 27.8 | 43.1 | 1.6 |
| | | Total eaten.....do.... | | 352.3 | 327.1 | 25.2 | 37.1 | 73.4 | 206.0 | 10.5 |
| 4 | Sheep D | Feces.....do.... | [1] 84.5 | 76.3 | 59.9 | 16.4 | 7.6 | 15.2 | 35.3 | 1.9 |
| | | Digested.....do.... | | 276.0 | 267.2 | 8.8 | 29.5 | 58.2 | 170.7 | 8.6 |
| | | .....do.....percent.. | | 78.34 | 81.69 | 34.92 | 79.51 | 79.29 | 82.86 | 81.90 |
| | | Silage.....grams.. | 2,500.0 | 608.8 | 560.9 | 47.9 | 61.9 | 139.4 | 343.1 | 16.6 |
| | | Feces.....do.... | [1] 203.4 | 186.5 | 157.1 | 29.4 | 22.4 | 50.2 | 81.4 | 3.1 |
| 4 | Sheep E | Digested.....do.... | | 422.3 | 403.8 | 18.5 | 39.5 | 89.2 | 261.7 | 13.5 |
| | | .....do.....percent.. | | 69.37 | 71.99 | 38.62 | 63.81 | 63.99 | 76.28 | 81.33 |
| | | Silage.....grams.. | 1,815.0 | 442.0 | 407.3 | 34.7 | 44.9 | 101.2 | 249.1 | 12.1 |
| | | Feed residue.....do.... | [1] 111.7 | 105.6 | 96.9 | 8.7 | 8.8 | 31.1 | 55.5 | 1.5 |
| | | Total eaten.....do.... | | 336.4 | 310.4 | 26.0 | 36.1 | 70.1 | 193.6 | 10.6 |
| 4 | Sheep F | Feces.....do.... | [1] 92.4 | 83.8 | 66.6 | 17.2 | 11.7 | 18.3 | 34.7 | 1.8 |
| | | Digested.....do.... | | 252.6 | 243.8 | 8.8 | 24.4 | 51.8 | 158.9 | 8.8 |
| | | .....do.....percent.. | | 75.09 | 78.54 | 33.85 | 67.59 | 73.89 | 82.08 | 83.02 |
| | | Silage.....pounds.. | 30.000 | 9.141 | 8.493 | .648 | .758 | 2.055 | 5.426 | .254 |
| | | Feed residue.....do.... | .103 | .095 | .088 | .007 | .008 | .024 | .053 | .003 |
| | | Total eaten.....do.... | | 9.046 | 8.405 | .641 | .750 | 2.031 | 5.373 | .251 |
| 15 | Steer C–22 | Feces.....do.... | 14.311 | 2.899 | 2.519 | .380 | .339 | .790 | 1.346 | .044 |
| | | Digested.....do.... | 15.586 | 6.147 | 5.886 | .261 | .411 | 1.241 | 4.028 | .207 |
| | | .....do.....percent.. | | 67.95 | 70.03 | 40.72 | 54.80 | 61.10 | 74.97 | 82.47 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 | Steer D-22 | Silage—pounds | 30.000 | 9.141 | 8.493 | .648 | .758 | 2.055 | 5.426 | .254 |
| | | Feces—do | 21.915 | 3.401 | 2.989 | .412 | .414 | .939 | 1.583 | .053 |
| | | Digested—do | | 5.740 | 5.504 | 2.36 | .344 | 1.116 | 3.843 | .201 |
| | | do—percent | | 62.79 | 64.81 | 36.42 | 45.38 | 54.31 | 70.83 | 79.13 |
| | | Alfalfa and sweet clover hays: | | | | | | | | |
| 15 | Steer A-22 | Alfalfa hay—pounds | 11.000 | 9.415 | 8.436 | .979 | 1.570 | 3.354 | 3.394 | .118 |
| | | Feces—do | 18.867 | 4.024 | 3.467 | .557 | .478 | 1.831 | 1.054 | .104 |
| | | Digested—do | | 5.391 | 4.969 | .422 | 1.092 | 1.523 | 2.340 | .014 |
| | | do—percent | | 57.26 | 58.90 | 43.11 | 69.55 | 45.41 | 68.95 | 11.86 |
| 16 | Steer B-22 | Alfalfa hay—pounds | 11.000 | 9.415 | 8.436 | .979 | 1.570 | 3.354 | 3.394 | .118 |
| | | Feces—do | 23.255 | 4.072 | 3.486 | .586 | .483 | 1.826 | 1.062 | .115 |
| | | Digested—do | | 5.343 | 4.950 | .393 | 1.087 | 1.528 | 2.332 | .003 |
| | | do—percent | | 56.75 | 58.68 | 40.14 | 69.24 | 45.56 | 68.71 | 2.54 |
| 18 | Steer A-24 | Alfalfa hay—pounds | 10.000 | 8.481 | 7.641 | .840 | 1.455 | 2.729 | 3.263 | .193 |
| | | Feces—do | 16.784 | 3.657 | 3.223 | .434 | .422 | 1.768 | .908 | .125 |
| | | Digested—do | | 4.824 | 4.418 | .406 | 1.033 | .961 | 2.355 | .068 |
| | | do—percent | | 56.88 | 57.81 | 48.33 | 71.00 | 35.21 | 72.17 | 35.23 |
| 18 | Steer B-24 | Alfalfa hay—pounds | 10.000 | 8.481 | 7.641 | .840 | 1.455 | 2.729 | 3.263 | .193 |
| | | Feces—do | 16.204 | 3.615 | 3.184 | .431 | .440 | 1.742 | .882 | .119 |
| | | Digested—do | | 4.866 | 4.457 | .409 | 1.015 | .987 | 2.381 | .074 |
| | | do—percent | | 57.38 | 58.33 | 48.69 | 69.76 | 36.17 | 72.97 | 38.34 |
| 18 | Steer C-24 | Alfalfa hay—pounds | 10.000 | 8.481 | 7.641 | .840 | 1.455 | 2.729 | 3.263 | .193 |
| | | Feces—do | 17.256 | 3.556 | 3.122 | .434 | .434 | 1.694 | .865 | .129 |
| | | Digested—do | | 4.925 | 4.519 | .406 | 1.021 | 1.035 | 2.398 | .064 |
| | | do—percent | | 58.07 | 59.14 | 48.33 | 70.17 | 37.93 | 73.49 | 33.16 |
| 18 | Steer D-24 | Alfalfa hay—pounds | 9.000 | 7.633 | 6.877 | .756 | 1.310 | 2.456 | 2.937 | .174 |
| | | Feces—do | 15.892 | 3.283 | 2.901 | .382 | .394 | 1.593 | .799 | .115 |
| | | Digested—do | | 4.350 | 3.976 | .374 | .916 | .863 | 2.138 | .059 |
| | | do—percent | | 56.99 | 57.82 | 49.47 | 69.92 | 35.14 | 72.80 | 33.91 |
| 22, subperiod *a* | Steer C-24 | Alfalfa hay—pounds | 13.000 | 11.094 | 10.041 | 1.053 | 1.863 | 3.762 | 4.213 | .203 |
| | | Feces—do | 21.878 | 4.411 | 3.934 | .477 | .543 | 2.149 | 1.096 | .146 |
| | | Digested—do | | 6.683 | 6.107 | .576 | 1.320 | 1.613 | 3.117 | .057 |
| | | do—percent | | 60.24 | 60.82 | 54.70 | 70.85 | 42.88 | 73.99 | 28.08 |
| 22, subperiod *b* | Steer C-24 | Alfalfa hay—pounds | 13.000 | 11.094 | 10.041 | 1.053 | 1.863 | 3.762 | 4.213 | .203 |
| | | Feces—do | 23.018 | 4.640 | 4.144 | .496 | .559 | 2.349 | 1.091 | .145 |
| | | Digested—do | | 6.454 | 5.897 | .557 | 1.304 | 1.413 | 3.122 | .058 |
| | | do—percent | | 58.18 | 58.73 | 52.90 | 69.99 | 37.56 | 74.10 | 28.57 |
| 22, subperiod *a* | Steer D-24 | Alfalfa hay—pounds | 13.000 | 11.094 | 10.041 | 1.053 | 1.863 | 3.762 | 4.213 | .203 |
| | | Feces—do | 23.640 | 4.655 | 4.158 | .497 | .552 | 2.304 | 1.150 | .152 |
| | | Digested—do | | 6.439 | 5.883 | .556 | 1.311 | 1.458 | 3.063 | .051 |
| | | do—percent | | 58.04 | 58.59 | 52.80 | 70.37 | 38.76 | 72.70 | 25.12 |
| 22, supberiod *b* | Steer D-24 | Alfalfa hay—pounds | 13.000 | 11.094 | 10.041 | 1.053 | 1.863 | 3.762 | 4.213 | .203 |
| | | Feces—do | 23.621 | 4.693 | 4.174 | .519 | .560 | 2.323 | 1.132 | .159 |
| | | Digested—do | | 6.401 | 5.867 | .534 | 1.303 | 1.439 | 3.081 | .044 |
| | | do—percent | | 57.70 | 58.43 | 50.71 | 69.94 | 38.25 | 73.13 | 21.67 |
| 5 | Sheep A | Sweetclover hay, first cutting—grams | 680.0 | 560.7 | 501.8 | 58.9 | 91.2 | 217.7 | 183.1 | 9.9 |
| | | Feces—do | 266.3 | 242.0 | 225.8 | 16.2 | 22.5 | 127.3 | 69.8 | 6.2 |
| | | Digested—do | | 318.7 | 276.0 | 42.7 | 68.7 | 90.4 | 113.3 | 3.7 |
| | | do—percent | | 56.84 | 55.00 | 72.50 | 75.33 | 41.53 | 61.88 | 37.37 |

See footnotes at end of table.

TABLE 4.—*Digestibility of sweetclover-oat straw silage, sweetclover silage, sunflower silage, corn silage, alfalfa and sweetclover hays, and sweetclover stems, when fed to sheep and steers*—Continued

| Trial No. | Animal | Feeds and other items | Original weight | Dry matter | Organic matter | Ash | Crude protein | Crude fiber | N-free extract | Ether extract |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Alfalfa and sweet clover hays—Continued. | | | | | | | | |
| 6 | Sheep C | Sweetclover hay, second cutting, grams | | | | | | | | |
| | | Feces, grams | 453.0 | 374.1 | 346.6 | 27.5 | 69.1 | 135.2 | 135.8 | 6.5 |
| | | Digested, do | 175.2 | 150.0 | 148.3 | 11.7 | 16.4 | 81.8 | 45.2 | 4.8 |
| | | do | | 214.1 | 198.3 | 15.8 | 52.7 | 53.4 | 90.6 | 1.7 |
| | | do, percent | | 57.23 | 57.21 | 57.45 | 76.27 | 39.50 | 66.72 | 26.15 |
| 6 | Sheep D | Sweetclover hay, second cutting, grams | | | | | | | | |
| | | Feces, grams | 453.0 | 374.1 | 346.6 | 27.5 | 69.1 | 135.2 | 135.8 | 6.5 |
| | | Digested, do | 174.9 | 158.0 | 146.5 | 11.5 | 16.2 | 81.3 | 44.5 | 4.5 |
| | | do | | 216.1 | 200.1 | 16.0 | 52.9 | 53.9 | 91.3 | 2.0 |
| | | do, percent | | 57.77 | 57.73 | 58.18 | 76.56 | 39.87 | 67.23 | 30.77 |
| 7 | Sheep E | Sweetclover stems, grams | 453.0 | 386.5 | 362.2 | 24.3 | 36.4 | 202.1 | 120.0 | 3.7 |
| | | Corn meal, do | 225.0 | 193.1 | 189.1 | 3.9 | 21.0 | 6.8 | 153.8 | 7.5 |
| | | Total eaten, do | 678.0 | 579.6 | 551.4 | 28.2 | 57.4 | 208.9 | 273.8 | 11.2 |
| | | Feces, do | 248.7 | 229.2 | 216.9 | 12.3 | 17.1 | 125.5 | 71.2 | 3.1 |
| | | Digested, total ration, do | | 350.4 | 334.5 | 15.9 | 40.3 | 83.4 | 202.6 | 8.1 |
| | | Corn meal digested [2], do | | 173.8 | 171.0 | 2.8 | 15.5 | 3.9 | 144.6 | 7.0 |
| | | Stems digested [3], do | | 176.6 | 163.5 | 13.1 | 24.8 | 79.5 | 57.9 | 1.1 |
| | | do, percent | | 45.69 | 45.14 | 53.91 | 68.13 | 39.34 | 48.25 | 29.73 |
| | | Digested, entire ration, do | | 60.46 | 60.66 | 56.38 | 70.21 | 39.92 | 74.00 | 72.32 |

[1] Air-dried weight.
[2] Computed by use of coefficients of digestibility from Morrison (*8*).
[3] Indirectly computed.

## DIGESTIBILITY OF ALFALFA HAY, SWEETCLOVER HAY, AND SWEETCLOVER STEMS

Alfalfa hay was fed alone in some trials to furnish data for comparing trials the alfalfa formed a part of the mixed rations. The trials with sheep included some tests on sweetclover hay for comparison with alfalfa and with sweetclover silage. The detailed data on these trials are given in table 4 but the discussion of the data appears later in connection with the summary table 7.

## DIGESTIBILITY OF MIXED RATIONS

In the metabolism trials of 1923–24 the silages were fed alone in its digestibility with sweetclover hay and sweetclover silage. In otner certain trials and in combination with alfalfa hay and linseed meal in other trials. A ratio of 2 pounds of linseed meal to 5 pounds of alfalfa was maintained in all the trials where silages were fed. It was intended that the same ratio would be maintained in a trial with linseed meal and alfalfa alone, but this combination proved too laxative to feed in amounts sufficient for maintenance. The ratio was therefore changed to 2 pounds of linseed meal and 7 pounds of alfalfa. Two pounds of linseed meal per head furnished a surplus of protein in the rations containing the sweetclover silages, but it was fed to insure adequate protein in the rations containing corn silage.

In the trials of 1924–25, sweetclover silage was fed alone and with 2 pounds of alfalfa hay and 4 pounds of a concentrate mixture, consisting of 3 parts of ground barley and 1 part of linseed meal. The latter ration was similar to a ration fed in some other experiments.

The detailed data on the digestibility of the mixed rations are given in table 5.

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TABLE 5.—*Digestibility of mixed rations: Sweetclover, sunflower, and corn silages, alfalfa hay, and concentrates*

| Trial No. | Animal | Feeds and other items | Original weight | Dry matter | Organic matter | Ash | Crude protein | Crude fiber | N-free extract | Ether extract |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Steer C-22 | Sweetclover silage, early bloom ..... pounds | 25.000 | 8.368 | 7.598 | 0.770 | 1.534 | 2.503 | 3.303 | 0.259 |
| | | Alfalfa hay ..... do | 5.000 | 4.236 | 3.786 | .450 | .677 | 1.467 | 1.574 | .068 |
| | | Linseed meal ..... do | 2.000 | 1.775 | 1.656 | .120 | .693 | .166 | .666 | .131 |
| | | Total ..... do | 32.000 | 14.379 | 13.040 | 1.340 | 2.904 | 4.136 | 5.543 | .458 |
| | | Feed residue ..... do | [1] 263 | .244 | .219 | .026 | .039 | .087 | .088 | .004 |
| | | Total eaten ..... do | 31.737 | 14.135 | 12.821 | 1.314 | 2.865 | 4.049 | 5.455 | .454 |
| | | Feces ..... do | 29.770 | 5.725 | 5.139 | .586 | .800 | 2.504 | 1.652 | .183 |
| | | Digested ..... do | | 8.410 | 7.682 | .728 | 2.065 | 1.545 | 3.802 | .270 |
| | | do ..... percent | | 59.50 | 59.92 | 55.40 | 72.08 | 38.16 | 69.72 | 59.69 |
| 9 | Steer D-22 | Sweetclover silage, early bloom ..... pounds | 22.000 | 7.363 | 6.686 | .677 | 1.350 | 2.202 | 2.906 | .228 |
| | | Alfalfa hay ..... do | 5.000 | 4.236 | 3.786 | .450 | .677 | 1.467 | 1.574 | .068 |
| | | Linseed meal ..... do | 2.000 | 1.775 | 1.656 | .120 | .693 | .166 | .666 | .131 |
| | | Total ..... do | 29.000 | 13.374 | 12.127 | 1.247 | 2.720 | 3.835 | 5.146 | .427 |
| | | Feed residue ..... do | [1] 075 | .069 | .061 | .008 | .012 | .024 | .023 | .001 |
| | | Total eaten ..... do | 28.925 | 13.305 | 12.066 | 1.239 | 2.708 | 3.811 | 5.123 | .426 |
| | | Feces ..... do | 29.038 | 5.328 | 4.762 | .566 | .724 | 2.310 | 1.569 | .159 |
| | | Digested ..... do | | 7.977 | 7.305 | .673 | 1.984 | 1.501 | 3.554 | .267 |
| | | do ..... percent | | 59.95 | 60.53 | 54.32 | 73.26 | 39.39 | 69.37 | 62.68 |
| 11 | Steer C-22 | Sweetclover silage, full bloom ..... pounds | 20.000 | 6.532 | 5.882 | .650 | 1.395 | 2.090 | 2.219 | .178 |
| | | Alfalfa hay ..... do | 5.000 | 4.189 | 3.747 | .442 | .693 | 1.483 | 1.502 | .069 |
| | | Linseed meal ..... do | 2.000 | 1.771 | 1.652 | .119 | .699 | .165 | .655 | .131 |
| | | Total ..... do | 27.000 | 12.492 | 11.281 | 1.211 | 2.787 | 3.738 | 4.376 | .378 |
| | | Feed residue ..... do | [1] 2.085 | 1.852 | 1.653 | .199 | .432 | .612 | .559 | .050 |
| | | Total eaten ..... do | 24.089 | 10.640 | 9.628 | 1.012 | 2.355 | 3.126 | 3.817 | .329 |
| | | Feces ..... do | | 4.143 | 3.674 | .469 | .585 | 1.820 | 1.147 | .122 |
| | | Digested ..... do | | 6.497 | 5.954 | .543 | 1.770 | 1.306 | 2.670 | .207 |
| | | do ..... percent | | 61.06 | 61.84 | 53.66 | 75.16 | 41.78 | 69.95 | 62.92 |
| 11 | Steer D-22 | Sweetclover silage, full bloom ..... pounds | 17.000 | 5.552 | 5.000 | .552 | 1.186 | 1.777 | 1.886 | .151 |
| | | Alfalfa hay ..... do | 5.000 | 4.189 | 3.747 | .442 | .693 | 1.483 | 1.502 | .069 |
| | | Linseed meal ..... do | 2.000 | 1.771 | 1.652 | .119 | .699 | .165 | .655 | .132 |
| | | Total eaten ..... do | 24.000 | 11.512 | 10.399 | 1.113 | 2.578 | 3.425 | 4.043 | .352 |
| | | Feces ..... do | 27.046 | 4.511 | 4.040 | .471 | .638 | 2.008 | 1.266 | .128 |
| | | Digested ..... do | | 7.001 | 6.359 | .642 | 1.940 | 1.417 | 2.777 | .224 |
| | | do ..... percent | | 60.81 | 61.15 | 57.68 | 75.25 | 41.37 | 68.69 | 63.64 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 19, subperiod a | Steer A-24 | Sweetclover silage, early bloom, pounds | 16.000 | 3.814 | 3.423 | .391 | .790 | 1.280 | 1.219 | .134 |
| | | Alfalfa hay, do | 2.000 | 1.690 | 1.526 | .164 | .294 | .542 | .652 | .039 |
| | | Grain mixture [2], do | 4.000 | 3.466 | 3.328 | .138 | .670 | .257 | 2.293 | .107 |
| | | Total eaten, do | | 8.970 | 8.277 | .693 | 1.754 | 2.079 | 4.164 | .280 |
| | | Feces, do | 17.823 | 3.210 | 2.883 | .327 | .463 | 1.266 | 1.037 | .117 |
| | | Digested, do | | 5.760 | 5.394 | .366 | 1.291 | .813 | 3.127 | .163 |
| | | do, percent | | 64.21 | 65.17 | 52.81 | 73.60 | 39.11 | 75.10 | 58.21 |
| 19, subperiod b | Steer A-24 | Sweetclover silage, early bloom, pounds | 16.000 | 3.874 | 3.478 | .396 | .823 | 1.255 | 1.264 | .136 |
| | | Alfalfa hay, do | 2.000 | 1.690 | 1.526 | .164 | .294 | .542 | .652 | .039 |
| | | Grain mixture [2], do | 4.000 | 3.466 | 3.328 | .138 | .670 | .257 | 2.293 | .107 |
| | | Total eaten, do | | 9.030 | 8.331 | .698 | 1.787 | 2.054 | 4.209 | .282 |
| | | Feces, do | 17.073 | 3.106 | 2.780 | .326 | .453 | 1.259 | .959 | .109 |
| | | Digested, do | | 5.924 | 5.552 | .372 | 1.334 | .795 | 3.250 | .173 |
| | | do, percent | | 65.60 | 66.63 | 53.30 | 74.65 | 38.70 | 77.22 | 61.35 |
| 19, subperiod a | Steer B-24 | Sweetclover silage, early bloom, pounds | 16.000 | 3.814 | 3.423 | .391 | .790 | 1.281 | 1.219 | .134 |
| | | Alfalfa hay, do | 2.000 | 1.690 | 1.526 | .164 | .294 | .542 | .652 | .039 |
| | | Grain mixture [2], do | 4.000 | 3.466 | 3.328 | .138 | .670 | .257 | 2.293 | .107 |
| | | Total eaten, do | | 8.970 | 8.277 | .693 | 1.754 | 2.079 | 4.164 | .280 |
| | | Feces, do | 14.818 | 3.069 | 2.737 | .332 | .467 | 1.247 | .923 | .100 |
| | | Digested, do | | 5.901 | 5.540 | .361 | 1.287 | .832 | 3.241 | .180 |
| | | do, percent | | 65.79 | 66.93 | 52.09 | 73.38 | 40.02 | 77.83 | 64.29 |
| 19, subperiod b | Steer B-24 | Sweetclover silage, early bloom, pounds | 16.000 | 3.874 | 3.478 | .396 | .823 | 1.255 | 1.264 | .136 |
| | | Alfalfa hay, do | 2.000 | 1.690 | 1.526 | .164 | .294 | .542 | .652 | .039 |
| | | Grain mixture [2], do | 4.000 | 3.466 | 3.328 | .138 | .670 | .257 | 2.293 | .107 |
| | | Total eaten, do | | 9.030 | 8.332 | .698 | 1.787 | 2.054 | 4.209 | .282 |
| | | Feces, do | 15.418 | 3.031 | 2.723 | .308 | .448 | 1.214 | .961 | .100 |
| | | Digested, do | | 5.999 | 5.609 | .390 | 1.339 | .840 | 3.248 | .182 |
| | | do, percent | | 66.43 | 67.32 | 55.87 | 74.93 | 40.90 | 77.17 | 64.54 |
| 19, subperiod a | Steer C-24 | Sweetclover silage, early bloom, pounds | 16.000 | 3.814 | 3.423 | .391 | .790 | 1.280 | 1.219 | .134 |
| | | Alfalfa hay, do | 2.000 | 1.690 | 1.526 | .164 | .294 | .542 | .652 | .039 |
| | | Grain mixture [2], do | 4.000 | 3.466 | 3.328 | .138 | .670 | .257 | 2.293 | .107 |
| | | Total eaten, do | | 8.970 | 8.277 | .693 | 1.754 | 2.079 | 4.164 | .280 |
| | | Feces, do | 15.276 | 3.006 | 2.682 | .324 | .421 | 1.211 | .945 | .105 |
| | | Digested, do | | 5.964 | 5.595 | .369 | 1.333 | .868 | 3.219 | .175 |
| | | do, percent | | 66.49 | 67.60 | 53.25 | 76.00 | 41.75 | 77.31 | 62.50 |

See footnotes at end of table.

TABLE 5.—*Digestibility of mixed rations: Sweetclover, sunflower, and corn silages, alfalfa hay, and concentrates*—Continued

| Trial No. | Animal | Feeds and other items | Original weight | Dry matter | Organic matter | Ash | Crude protein | Crude fiber | N-free extract | Ether extract |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Sweetclover silage, early bloom ..... pounds | 16.000 | 3.874 | 3.478 | 0.396 | 0.823 | 1.255 | 1.264 | 0.136 |
| | | Alfalfa hay ..... do | 2.000 | 1.690 | 1.526 | .164 | .294 | .542 | .652 | .039 |
| | | Grain mixture [2] ..... do | 4.000 | 3.466 | 3.328 | .138 | .670 | .257 | 2.293 | .107 |
| 19, subperiod b | Steer C-24 | Total eaten ..... | ..... | 9.030 | 8.332 | .698 | 1.787 | 2.054 | 4.209 | .282 |
| | | Feces ..... do | 14.814 | 2.886 | 2.591 | .295 | .397 | 1.194 | .899 | .101 |
| | | Digested ..... do | ..... | 6.144 | 5.741 | .403 | 1.390 | .860 | 3.310 | .181 |
| | | ..... do ..... percent | ..... | 68.04 | 68.90 | 57.74 | 77.78 | 41.87 | 7.864 | 64.18 |
| | | Sweetclover silage, early bloom ..... pounds | 16.000 | 3.814 | 3.423 | .391 | .790 | 1.280 | 1.219 | .134 |
| | | Alfalfa hay ..... do | 2.000 | 1.690 | 1.526 | .164 | .294 | .542 | .652 | .039 |
| | | Grain mixture [2] ..... do | 4.000 | 3.466 | 3.327 | .138 | .670 | .257 | 2.293 | .107 |
| 19, subperiod a | Steer D-24 | Total eaten ..... do | ..... | 8.970 | 8.278 | .693 | 1.754 | 2.079 | 4.164 | .280 |
| | | Feces ..... do | 15.453 | 2.959 | 2.636 | .323 | .415 | 1.210 | .913 | .098 |
| | | Digested ..... do | ..... | 6.011 | 5.641 | .370 | 1.339 | .869 | 3.251 | .182 |
| | | ..... do ..... percent | ..... | 67.01 | 68.15 | 53.39 | 76.34 | 41.80 | 78.07 | 65.00 |
| | | Sweetclover silage, early bloom ..... pounds | 16.000 | 3.874 | 3.478 | .396 | .823 | 1.255 | 1.264 | .136 |
| | | Alfalfa hay ..... do | 2.000 | 1.690 | 1.526 | .164 | .294 | .542 | .652 | .039 |
| | | Grain mixture [2] ..... | 4.000 | 3.466 | 3.328 | .138 | .670 | .257 | 2.293 | .107 |
| 19, subperiod b | ..... do ..... | Total eaten ..... do | ..... | 9.030 | 8.332 | .698 | 1.787 | 2.054 | 4.209 | .282 |
| | | Feces ..... do | 15.524 | 3.033 | 2.715 | .318 | .416 | 1.292 | .905 | .102 |
| | | Digested ..... do | ..... | 5.997 | 5.617 | .380 | 1.371 | .762 | 3.304 | .180 |
| | | ..... do ..... percent | ..... | 66.41 | 67.41 | 54.44 | 76.72 | 37.10 | 78.50 | 63.83 |
| | | Sunflower silage ..... pounds | 14.000 | 3.647 | 3.100 | .547 | .299 | 1.391 | 1.333 | .077 |
| | | Alfalfa hay ..... do | 5.000 | 4.301 | 3.860 | .441 | .696 | 1.534 | 1.568 | .062 |
| | | Linseed meal ..... do | 2.000 | 1.761 | 1.642 | .119 | .702 | .166 | .647 | .127 |
| 12 | Steer A-22 | Total ..... do | ..... | 9.709 | 8.602 | 1.107 | 1.697 | 3.091 | 3.548 | .266 |
| | | Feces ..... do | 16.092 | 3.988 | 3.561 | .427 | .452 | 1.808 | 1.233 | .068 |
| | | Digested ..... do | ..... | 5.721 | 5.041 | .680 | 1.245 | 1.283 | 2.315 | .198 |
| | | ..... do ..... percent | ..... | 58.92 | 58.60 | 61.43 | 73.36 | 41.51 | 65.25 | 74.44 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Sunflower silage | pounds | 14.000 | 3.647 | 3.100 | .547 | .299 | 1.391 | 1.333 | .077 |
| | | Alfalfa hay | do | 5.000 | 4.301 | 3.860 | .441 | .696 | 1.534 | 1.568 | .062 |
| | | Linseed meal | do | 2.000 | 1.761 | 1.642 | .119 | .702 | .166 | .647 | .127 |
| 12 | Steer B-22 | Total | do | | 9.709 | 8.602 | 1.107 | 1.697 | 3.091 | 3.548 | .266 |
| | | Feces | do | 20.285 | 3.970 | 3.529 | .441 | .480 | 1.772 | 1.205 | .073 |
| | | Digested | do | | 5.739 | 5.073 | .666 | 1.217 | 1.319 | 2.343 | .193 |
| | | do | percent | | 59.11 | 58.97 | 60.16 | 71.71 | 42.67 | 66.04 | 72.56 |
| | | Corn silage | pounds | 20.000 | 6.094 | 5.662 | .432 | .505 | 1.370 | 3.617 | .169 |
| | | Alfalfa hay | do | 5.000 | 4.320 | 3.912 | .408 | .647 | 1.686 | 1.519 | .060 |
| | | Linseed meal | do | 2.000 | 1.770 | 1.650 | .121 | .702 | .160 | .666 | .121 |
| 14 | Steer A-22 | Total | do | | 12.184 | 11.224 | .961 | 1.854 | 3.216 | 5.802 | .350 |
| | | Feed residue [3] | do | [3] 612 | .565 | .513 | .051 | .139 | .149 | .209 | .017 |
| | | Total eaten | do | | 11.619 | 10.711 | .910 | 1.715 | 3.067 | 5.593 | .333 |
| | | Feces | do | 18.310 | 3.924 | 3.423 | .501 | .567 | 1.457 | 1.313 | .086 |
| | | Digested | do | | 7.695 | 7.288 | .409 | 1.148 | 1.610 | 4.280 | .247 |
| | | do | percent | | 66.23 | 68.04 | 44.95 | 66.94 | 52.49 | 76.52 | 74.17 |
| | | Corn silage | pounds | 20.000 | 6.094 | 5.662 | .432 | .505 | 1.370 | 3.617 | .169 |
| | | Alfalfa hay | do | 5.000 | 4.320 | 3.912 | .408 | .647 | 1.686 | 1.519 | .060 |
| | | Linseed meal | do | 2.000 | 1.770 | 1.650 | .121 | .702 | .160 | .666 | .121 |
| | | Total | do | | 12.184 | 11.224 | .961 | 1.854 | 3.216 | 5.802 | .350 |
| 14 | Steer B-22 | Feed residue [3] | do | [3] 1.838 | 1.608 | 1.550 | .148 | .286 | .649 | .583 | .032 |
| | | Feed residue [4] | do | [4] .032 | .029 | .027 | .002 | .003 | .008 | .015 | .001 |
| | | Total residue | do | | 1.727 | 1.577 | .150 | .289 | .657 | .598 | .033 |
| | | Total eaten | do | | 10.457 | 9.647 | .811 | 1.565 | 2.559 | 5.204 | .317 |
| | | Feces | do | 21.470 | 3.860 | 3.311 | .549 | .528 | 1.255 | 1.452 | .078 |
| | | Digested | do | | 6.597 | 6.336 | .262 | 1.037 | 1.304 | 3.752 | .239 |
| | | do | percent | | 63.09 | 65.68 | 32.31 | 66.26 | 50.96 | 72.12 | 75.39 |
| | | Alfalfa hay | pounds | 7.000 | 5.991 | 5.368 | .623 | .999 | 2.134 | 2.160 | .075 |
| | | Linseed meal | do | 2.000 | 1.771 | 1.653 | .118 | .702 | .171 | .658 | .122 |
| 17 | Steer C-22 | Total | do | | 7.762 | 7.021 | .741 | 1.701 | 2.305 | 2.818 | .197 |
| | | Feces | do | 17.695 | 3.088 | 2.671 | .417 | .405 | 1.363 | .826 | .077 |
| | | Digested | do | | 4.674 | 4.350 | .324 | 1.296 | .942 | 1.992 | .120 |
| | | do | percent | | 60.22 | 61.96 | 43.72 | 76.19 | 40.87 | 70.69 | 60.91 |

See footnotes at end of table.

TABLE 5.—*Digestibility of mixed rations: Sweetclover, sunflower, and corn silages, alfalfa hay, and concentrates*—Continued

| Trial No. | Animal | Feeds and other items | Original weight | Dry matter | Organic matter | Ash | Crude protein | Crude fiber | N-free extract | Ether extract |
|---|---|---|---|---|---|---|---|---|---|---|
| 17 | Steer D-22 | Alfalfa hay, pounds | 7.000 | 5.991 | 5.368 | 0.623 | 0.999 | 2.134 | 2.160 | 0.075 |
| | | Linseed meal, do | 2.000 | 1.771 | 1.653 | .118 | .703 | .171 | .658 | .122 |
| | | Total, do | | 7.762 | 7.021 | .741 | 1.701 | 2.305 | 2.818 | .197 |
| | | Feces, do | 25.252 | 3.280 | 2.918 | .362 | .446 | 1.484 | .903 | .085 |
| | | Digested, do | | 4.482 | 4.103 | .379 | 1.255 | .821 | 1.915 | .112 |
| | | Digested, percent | | 57.74 | 58.44 | 51.15 | 73.78 | 35.62 | 67.96 | 56.85 |
| 21, subperiod a | Steer A-24 | Alfalfa hay, pounds | 8.000 | 6.827 | 6.179 | .648 | 1.146 | 2.315 | 2.593 | .125 |
| | | Wild oats, do | 8.000 | 7.046 | 6.735 | .311 | 1.937 | .092 | 4.282 | .424 |
| | | Total, do | 16.000 | 13.873 | 12.914 | .959 | 2.083 | 3.407 | 6.875 | .549 |
| | | Residue, do | 1.630 | 1.503 | 1.373 | .130 | .254 | .424 | .651 | .044 |
| | | Total eaten, do | 14.370 | 12.370 | 11.541 | .829 | 1.829 | 2.983 | 6.225 | .505 |
| | | Feces, do | 24.000 | 4.932 | 4.472 | .460 | .527 | 2.010 | 1.837 | .098 |
| | | Digested, do | | 7.438 | 7.069 | .369 | 1.302 | .973 | 4.388 | .407 |
| | | Digested, percent | | 60.13 | 61.25 | 44.51 | 71.19 | 32.62 | 70.49 | 80.59 |
| 21, subperiod b | Steer A-24 | Alfalfa hay, pounds | 8.000 | 6.827 | 6.179 | .648 | 1.146 | 2.315 | 2.593 | .125 |
| | | Wild oats, do | 8.000 | 7.046 | 6.735 | .311 | .937 | 1.092 | 4.282 | .424 |
| | | Total, do | 16.000 | 13.873 | 12.914 | .959 | 2.083 | 3.407 | 6.875 | .549 |
| | | Residue, do | 1.640 | 1.480 | 1.348 | .132 | .250 | .434 | .623 | .041 |
| | | Total eaten, do | 14.360 | 12.393 | 11.566 | .827 | 1.833 | 2.973 | 6.252 | .508 |
| | | Feces, do | 22.773 | 4.782 | 4.347 | .435 | .511 | 1.943 | 1.784 | .109 |
| | | Digested, do | | 7.611 | 7.218 | .392 | 1.322 | 1.030 | 4.468 | .399 |
| | | Digested, percent | | 61.41 | 62.41 | 47.40 | 72.12 | 34.65 | 71.47 | 78.54 |
| 21, subperiod a | Steer B-24 | Alfalfa hay, pounds | 8.000 | 6.827 | 6.179 | .648 | 1.146 | 2.315 | 2.593 | .125 |
| | | Wild oats, do | 8.000 | 7.046 | 6.735 | .311 | .937 | 1.092 | 4.282 | .424 |
| | | Total, do | 16.000 | 13.873 | 12.914 | .959 | 2.083 | 3.407 | 6.875 | .549 |
| | | Feces, do | 25.370 | 5.673 | 5.161 | .512 | .609 | 2.347 | 2.094 | .111 |
| | | Digested, do | | 8.200 | 7.753 | .447 | 1.474 | 1.060 | 4.781 | .438 |
| | | Digested, percent | | 59.11 | 60.04 | 46.61 | 70.76 | 31.11 | 69.54 | 79.78 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21, subperiod b | Steer B–24 | Alfalfa hay | pounds | 8.000 | 6.827 | 6.179 | .648 | 1.146 | 2.315 | 2.593 | .125 |
| | | Wild oats | do | 8.000 | 7.046 | 6.735 | .311 | .937 | 1.092 | 4.252 | .424 |
| | | Total | do | 16.000 | 13.873 | 12.914 | .959 | 2.083 | 3.407 | 6.875 | .549 |
| | | Feces | do | 24.815 | 5.683 | 5.163 | .520 | .611 | 2.394 | 2.040 | .117 |
| | | Digested | do | ---------- | 8.190 | 7.751 | .439 | 1.472 | 1.013 | 4.835 | .432 |
| | | do | percent | ---------- | 59.04 | 60.02 | 45.78 | 70.67 | 29.73 | 70.33 | 78.69 |

[1] Sweetclover silage residue, air-dried weight.
[2] Ground barley, 3 parts; linseed meal, 1 part.
[3] Alfalfa and linseed-meal residues.
[4] Corn-silage residue.

## COEFFICIENTS OF DIGESTIBILITY, INDIRECTLY COMPUTED

Since the ratio of alfalfa hay to linseed meal was constant in the different trials of 1923–24, excepting trial 17, it was possible to compute the digestibility of some of the components of the mixed rations. By applying the coefficients of digestibility of the sweetclover silages obtained with steers A–22 and B–22 in trials 8 and 10 to the data of steers C–22 and D–22 in trials 9 and 11, it was possible to compute the digestibility of linseed meal and alfalfa hay when combined in the ratio of 2 to 5, respectively. The coefficients thus computed were applied to the data of steers A–22 and B–22 in trials 12 and 14 in computing, indirectly, the digestibility of the sunflower and corn silages. The digestibility of the linseed meal was also computed by applying the determined coefficients of digestibility of alfalfa and the silages to the respective trials and obtaining the digestibility of the linseed meal by difference.

Similarly, in the trials of 1924–25, the digestibility of the grain mixture consisting of 3 parts of barley and 1 part of linseed meal was computed and also the digestibility of the wild oats.

The coefficients thus computed are given in table 6.

TABLE 6.—*Coefficients of digestibility of feed constituents, indirectly computed*

| Trial No. | Animal No. | Feeds | Dry matter | Organic matter | Crude protein | Crude fiber | N-free extract | Ether extract |
|---|---|---|---|---|---|---|---|---|
| | | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| 9 | C–22 | Alfalfa 5 parts and linseed meal 2 parts | 60.6 | 61.7 | 74.6 | 38.6 | 70.5 | 60.5 |
| | D–22 | | 61.5 | 62.8 | 76.8 | 41.1 | 69.8 | 66.9 |
| | | Average | 61.1 | 62.3 | 75.7 | 39.9 | 70.2 | 63.7 |
| 11 | C–22 | Alfalfa 5 parts and linseed meal 2 parts | 61.9 | 63.4 | 77.2 | 40.9 | 70.9 | 72.0 |
| | D–22 | | 61.6 | 62.5 | 77.0 | 39.1 | 69.9 | 75.1 |
| | | Average | 61.8 | 63.0 | 77.1 | 40.0 | 70.4 | 73.6 |
| 12 | A–22 | Sunflower silage | 54.9 | 51.5 | 59.4 | 43.4 | 56.9 | 88.5 |
| | B–22 | do | 55.4 | 52.5 | 50.1 | 46.0 | 59.0 | 82.8 |
| | | Average | 55.2 | 52.0 | 54.8 | 44.7 | 58.0 | 85.7 |
| 14 | A–22 | Corn silage | 70.6 | 72.9 | 44.2 | 67.9 | 80.0 | 79.3 |
| | B–22 | do | 55.2 | 67.9 | 45.9 | 61.4 | 72.8 | 82.3 |
| | | Average | 62.9 | 70.4 | 45.1 | 64.7 | 76.4 | 80.8 |
| 9 | C–22 | Linseed meal | 69.1 | 68.2 | 79.7 | −122.0 | 74.4 | 88.3 |
| | D–22 | do | 72.1 | 72.1 | 84.0 | 2.5 | 72.0 | 97.9 |
| | | Average | 70.6 | 70.2 | 81.9 | −59.8 | 73.2 | 93.1 |
| 11 | C–22 | Linseed meal | 73.4 | 73.9 | 84.9 | −100.1 | 75.8 | 105.9 |
| | D–22 | do | 72.3 | 71.0 | 84.4 | −118.3 | 72.5 | 110.6 |
| | | Average | 72.9 | 72.5 | 84.7 | −109.2 | 74.2 | 108.3 |
| 12 | A–22 | Linseed meal | 71.5 | 70.6 | 85.3 | −116.3 | 71.7 | 100.6 |
| | B–22 | do | 72.6 | 72.6 | 81.3 | −100.2 | 76.0 | 97.1 |
| | | Average | 72.1 | 71.6 | 83.3 | −108.3 | 73.9 | 98.9 |
| 14 | A–22 | Linseed meal | 93.5 | 93.7 | 78.4 | 78.7 | 118.2 | 98.3 |
| | B–22 | do | 64.7 | 70.5 | 77.6 | 34.4 | 71.9 | 91.0 |
| | | Average | 79.1 | 82.1 | 78.0 | 56.6 | 95.1 | 94.7 |

TABLE 6.—*Coefficients of digestibility of feed constituents, indirectly computed*—Con.

| Trial No. | Animal No. | Feeds | Dry matter | Organic matter | Crude protein | Crude fiber | N-free extract | Ether extract |
|---|---|---|---|---|---|---|---|---|
| | | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| 17 | C–22 | Linseed meal | 71.1 | 72.3 | 85.9 | −116.9 | 76.8 | 94.3 |
| | D–22 | do | 60.3 | 57.3 | 80.0 | −187.9 | 65.1 | 87.7 |
| | | Average | 65.7 | 64.8 | 83.0 | −152.4 | 71.0 | 91.0 |
| | | Linseed meal [1] | 72.1 | 72.2 | 82.2 | −74.6 | 77.5 | 97.2 |
| | | do [2] | 70.3 | 69.8 | 83.2 | −107.4 | 73.1 | 97.8 |
| 19 | A–24 | Barley 3 parts and linseed meal 1 part | 69.9 | 71.4 | 69.3 | 25.3 | 78.7 | 60.3 |
| | B–24 | do | 73.0 | 74.4 | 69.4 | 37.8 | 81.1 | 72.4 |
| 19 | C–24 | do | 76.0 | 77.2 | 76.7 | 48.6 | 82.0 | 69.6 |
| | D–24 | do | 74.6 | 76.0 | 75.7 | 29.8 | 82.6 | 72.4 |
| | | Average | 73.4 | 74.8 | 72.8 | 35.4 | 81.1 | 68.7 |
| 21 | A–24 | Wild oats | 62.7 | 64.0 | 73.6 | 22.3 | 69.6 | 93.5 |
| | B–24 | do | 59.6 | 60.9 | 71.3 | 11.5 | 50.6 | 95.0 |
| | | Average | 61.2 | 62.5 | 72.5 | 16.9 | 60.1 | 94.3 |

[1] Average all trials.
[2] Average omitting trial No. 14.

Reference to table 6 shows that the average coefficients for alfalfa hay and linseed meal combined, as computed in trials 9 and 11, agree fairly with each other except for ether extract where the difference between the averages of the two trials is 10 percent. On the whole, these coefficients for alfalfa 5 parts and linseed meal 2 parts are, as would be expected, slightly higher but similar to the coefficients directly determined in trial 17 for alfalfa 7 parts and linseed meal 2 parts, table 7.

The indirectly computed coefficients for sunflower silage, trial 12, steers A–22 and B–22, agree within 3 percent of each other except for protein where the difference is 9.3 and for ether extract where the difference is 5.7. Compared to the single direct determination with steer C–22, trial 13, the indirectly computed coefficients are higher by 5.2 for dry matter, 3.5 for organic matter, 10.9 for crude protein, 5.0 for crude fiber, 0.8 for nitrogen-free extract and 13.2 for ether extract. Steer C–22 ate only enough sunflower silage to furnish 0.4 as much digestible crude protein and less than half as much digestible nutrients as are needed for maintenance on the basis of the feeding standards for maintenance proposed by Brody, Procter, and Ashworth (*2*). Steers A–22 and B–22, trial 12, consumed adequate amounts of protein but their rations were a little low in digestible nutrients. The low protein consumption by steer C–22 may account in part for the low digestibility of the crude protein by this steer.

The indirectly computed coefficients of digestibility for corn silage, steers A–22 and B–22, trial 14, differ by 15.4 for dry matter, 5.0 for organic matter, 1.7 for crude protein, 6.5 for crude fiber, 7.2 for nitrogen-free extract and 3.0 for ether extract. The wide difference in the coefficients for dry matter may be due in part to unavoidable errors in apportioning the alfalfa, linseed meal, and corn silage in the feed residues, especially with steer B–22. Except for the dry matter, the

digestion coefficients show about the same degree of variation between those computed indirectly, those determined directly, and between the averages of the two.

The computed digestion coefficients for linseed meal are rather unsatisfactory, particularly the coefficients for crude fiber which were negative by 100 or more in 7 out of 10 trials. If the results of trial 14 are omitted, the agreement among the coefficients for dry matter, organic matter, crude protein, nitrogen-free extract, and, to a lesser degree, for the ether extract, is fairly satisfactory. The relatively small amounts of linseed meal in the rations and the low fiber content of linseed meal tend to make the results somewhat uncertain. With trial 14 omitted, the average digestion coefficients for linseed meal are 83.2 for crude protein, −107.4 for crude fiber, 73.1 for nitrogen-free extract and 97.8 for ether extract.

## SUMMARY OF DIGESTION COEFFICIENTS

The average coefficients of digestibility for the different feeds and mixed rations are summarized in table 7.

Reference to table 7 shows that the sweetclover-oat straw silage was distinctly lower in digestibility of all nutrients except crude fiber than the sweetclover silage from the same crop (1922). Mixing 5.5 parts of freshly cut sweetclover with 1 part of dry oat straw gave a silage mixture in which only 53.6 percent of the dry matter was sweetclover. Compared to the sweetclover silage the inclusion of the straw reduced the coefficients of digestibility of dry matter from 56.9 to 33.9; organic matter from 56.6 to 35.1; crude protein from 76.8 to 51.5; nitrogen-free extract from 58.0 to 12.8; ether extract from 62.8 to 55.6, while the coefficients for the crude fiber remained virtually identical.

A comparison of the sweetclover silage of 1922, trial 2, with the first and second cuttings of sweetclover hay, the same year, trials 5 and 6, shows that the coefficients are essentially alike, except for the notably lower digestibility of the ether extract in the hays. Similar relationships are noted in comparing the digestibility of the sweet clover silages and alfalfa hays.

The coefficients from a single trial on the sweetclover stems are about the same for crude fiber and ether extract as those for the second cutting of sweetclover hay cut in early bloom, but are lower for all the other nutrients.

The sweetclover silage, full bloom, trial 10, with its higher fiber content, gave slightly higher coefficients of digestibility for dry matter, organic matter, crude protein, and crude fiber, but lower coefficients for nitrogen-free extract and ether extract than the silage from the sweetclover cut in early bloom, trial 8. The sweetclover silage of 1924, trial 20, gave consistently higher coefficients for all nutrients, except for crude fiber in trial 10, than the silages of the two preceding years. This silage was superior in appearance and palatability to the silages fed in the preceding years. The sweetclover silages were not relished at first by either the sheep or steers, but after acquiring a taste for them they ate them readily.

TABLE 7.—*Summary of digestion-coefficient data for the various feeds*

| Feeds | Trial No. | Experimental animals | Individual trials | Year of experiment | Dry matter | Organic matter | Crude protein | Crude fiber | N-free extract | Ether extract |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Number* | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Sweetclover-oat straw silage | 1 | Sheep | 2 | 1922-23 | 33.9 | 35.1 | 51.5 | 41.7 | 12.8 | 55.6 |
| Sweetclover silage, bud stage | 2 | do | 3 | 1922-23 | 56.9 | 56.6 | 76.8 | 41.8 | 58.0 | 62.8 |
| Sweetclover silage, early bloom | 8 | Steers | 2 | 1923-24 | 58.7 | 58.6 | 69.7 | 38.2 | 69.0 | 58.7 |
| Sweetclover silage, full bloom | 10 | do | 2 | 1923-24 | 60.0 | 59.7 | 73.3 | 43.4 | 67.3 | 48.6 |
| Sweetclover silage, early bloom | 20 | do | [1] 4 | 1924-25 | 63.7 | 64.0 | 79.6 | 42.8 | 73.3 | 66.3 |
| Sweetclover hay, first cutting, early bloom, ground | 5 | Sheep | 1 | 1922-23 | 56.8 | 55.0 | 75.3 | 41.5 | 61.9 | 37.4 |
| Sweetclover hay, second cutting, early bloom, ground | 6 | do | 2 | 1922-23 | 57.5 | 57.5 | 76.4 | 39.7 | 67.0 | 28.5 |
| Sweetclover, chiefly stems, ground | 7 | do | 1 | 1922-23 | 45.7 | 45.1 | 68.1 | 39.3 | 48.3 | 29.6 |
| Alfalfa hay | 16 | Steers | 2 | 1923-24 | 57.0 | 58.8 | 69.4 | 45.5 | 68.8 | 7.2 |
| | 18 | do | 4 | 1924-25 | 57.3 | 58.3 | 70.2 | 36.1 | 72.9 | 35.1 |
| | 22 | do | 2 | 1924-25 | 58.5 | 59.1 | 70.3 | 39.4 | 73.5 | 25.9 |
| Sunflower silage | 3 | Sheep | 3 | 1922-23 | 52.5 | 53.2 | 51.1 | 42.0 | 59.8 | 65.9 |
| | 13 | Steers | 1 | 1923-24 | 50.0 | 48.5 | 43.9 | 39.7 | 57.2 | 72.5 |
| | 12 | do | [2] 2 | 1923-24 | 55.2 | 52.0 | 54.8 | 44.7 | 58.0 | 85.7 |
| Average | | do | 3 | 1923-24 | 53.5 | 50.8 | 51.2 | 43.0 | 57.7 | 81.3 |
| Corn silage | 4 | Sheep | 3 | 1922-23 | 73.3 | 76.3 | 69.1 | 70.4 | 79.6 | 82.0 |
| | 15 | Steers | 2 | 1923-24 | 65.4 | 67.4 | 50.1 | 57.7 | 72.9 | 80.8 |
| | 14 | do | [2] 2 | 1923-24 | 62.9 | 70.4 | 45.1 | 64.7 | 76.4 | 80.8 |
| Sweetclover silage, early bloom, alfalfa hay, and linseed meal | 9 | do | 2 | 1923-24 | 59.7 | 60.2 | 72.7 | 38.8 | 69.6 | 61.1 |
| Sweetclover silage, full bloom, alfalfa hay, and linseed meal | 11 | do | 2 | 1923-24 | 60.9 | 61.5 | 75.2 | 41.6 | 69.3 | 63.3 |
| Sweetclover silage, alfalfa hay, and grain mixture | 19 | do | [1] 4 | 1924-25 | 66.3 | 67.3 | 75.4 | 40.2 | 77.5 | 63.0 |
| Alfalfa hay, 5 parts; linseed meal, 2 parts | 9 and 11. | do | 4 | 1923-24 | 61.5 | 62.7 | 71.4 | 39.0 | 70.3 | 73.7 |
| Alfalfa hay, 7 parts; linseed meal, 2 parts | 17 | do | 2 | 1923-24 | 59.0 | 60.2 | 75.0 | 38.2 | 69.3 | 58.9 |
| Alfalfa hay and wild oats | 21 | do | [2] 2 | 1924-25 | 59.9 | 60.9 | 71.2 | 31.9 | 70.4 | 79.4 |
| Sunflower silage, alfalfa hay, and linseed meal | 12 | do | 2 | 1923-24 | 59.0 | 58.8 | 72.5 | 42.1 | 65.6 | 73.5 |
| Corn silage, alfalfa hay, and linseed meal | 14 | do | 2 | 1923-24 | 64.7 | 66.9 | 66.6 | 51.8 | 74.4 | 74.8 |
| Linseed meal | | do | 8 | 1923-24 | 70.3 | 69.8 | 83.2 | −107.4 | 73.1 | 97.8 |
| Linseed meal, Morrison [4] | | do | 9 | | | | 87.0 | 59.0 | 82.0 | 92.0 |
| Barley, 3 parts; linseed meal, 1 part | 19 | do | 4 | 1924-25 | 78.1 | 79.2 | 76.8 | 55.4 | 83.6 | 74.4 |
| Wild oats | 21 | do | [2] 2 | 1924-25 | 61.2 | 62.5 | 72.5 | 16.9 | 60.1 | 94.3 |
| Oats, common, Morrison [4] | | | 19 | | | | 78.0 | 38.0 | 81.0 | 88.0 |

[1] The trials covered 18 days, with 9-day subperiods.
[2] Digestibility indirectly computed.
[3] This 20-day period was divided into subperiods of 10 days each.
[4] Morrison (*8*).

The sunflower silages were unpalatable and both sheep and steers refused to eat them when first offered. One steer would not eat them at all and the other ate less than a maintenance ration. Compared to corn silage the sunflower silage gave notably lower digestion coefficients for all nutrients except crude protein.

The corn silage was palatable and gave distinctly higher coefficients than the sweetclover or sunflower silages except for crude protein.

For comparison the average coefficients for linseed meal from nine trials as given by Morrison (*8*) are included in table 7. Morrison's averages are higher for protein, crude fiber, and nitrogen-free extract, but lower for ether extract than were those of the eight linseed-meal tests recorded.

The wild oats fed in these trials were heavier than the usual run, weighing 37.5 pounds to the bushel. Compared to Morrison's (*8*) average coefficients for common or cultivated oats, they are somewhat lower except for ether extract. Additional trials are needed before the data can be considered representative of wild oats.

## APPARENT AND "TRUE" DIGESTIBILITY OF PROTEIN

Both the sunflower and corn silages had wide nutritive ratios and low apparent digestibility of the protein. Reference to table 8 shows that the low digestibility of the crude protein is more apparent than real. When correction is made for the metabolic nitrogen by the methods of either Mitchell (*7*) or Titus (*9*), the "true" digestibility does not vary greatly in the different feeds.

TABLE 8.—*Apparent and "true" digestibility of protein in silages and alfalfa hay, crops of 1923*

| Silage or hay | Trial No. | Digestibility of protein | | | Nutritive ratio 1:— |
|---|---|---|---|---|---|
| | | Apparent | True | | |
| | | | Mitchell | Titus [1] | |
| | | *Percent* | *Percent* | *Percent* | |
| Sweetclover silage | 8 | 69.7 | 86.7 | 85.5 | 3.4 |
| | 10 | 73.3 | 87.9 | 88.2 | 2.5 |
| Sunflower silage | 8 | 48.5 | 82.0 | 82.7 | 11.0 |
| Corn silage | 15 | 50.1 | 87.7 | 87.7 | 41.8 |
| Alfalfa hay | 17 | 69.4 | 88.1 | 89.1 | 3.6 |

[1] Formula 2.

## DIGESTIBLE NUTRIENTS IN FEEDS

The percentages of dry matter in the feeds and the digestible crude protein and total digestible nutrients in the feeds, both as fed and on a dry-matter basis, are given in table 9.

TABLE 9.—*Percentages of dry matter, digestible crude protein, and total digestible nutrients in feeds*

| Feeds | Year of experiment | Trial No. | Experimental animals | Individual trials | As fed | | | In dry matter | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Dry matter | Digestible crude protein | Total digestible nutrients | Digestible crude protein | Total digestible nutrients |
| | | | | *Number* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Sweetclover-oat-straw silage | 1922–23 | 1 | Sheep | 2 | 21.97 | 1.6 | 7.4 | 7.3 | 33.7 |
| Sweetclover silage, bud stage | 1922–23 | 2 | do | 3 | 34.78 | 5.8 | 18.6 | 16.7 | 53.5 |
| Sweetclover silage, early bloom | 1923–24 | 8 | Steers | 2 | 33.47 | 4.3 | 18.6 | 12.8 | 55.6 |
| Sweetclover silage, full bloom | 1923–24 | 10 | do | 2 | 32.66 | 5.1 | 18.1 | 15.6 | 55.4 |
| Sweetclover silage, early bloom | 1924–25 | 20 | do | 4 | 24.70 | 4.4 | 15.0 | 17.9 | 60.7 |
| Average | | | | 11 | 30.49 | 4.9 | 17.2 | 16.2 | 56.8 |
| Sweetclover hay, first cutting, ground | 1922–23 | 5 | Sheep | 1 | 82.46 | 10.1 | 41.3 | 12.3 | 50.1 |
| Sweetclover hay, second cutting, ground | 1922–23 | 6 | do | 2 | 82.58 | 11.6 | 44.5 | 14.0 | 53.9 |
| Average | | | | 3 | 82.54 | 11.1 | 43.4 | 13.4 | 52.6 |
| Sweetclover, chiefly stems, ground | 1922–23 | 7 | Sheep | 1 | 85.33 | 5.5 | 36.4 | 6.4 | 42.7 |
| Alfalfa hay | 1923–24 | 16 | Steers | 2 | 84.59 | 9.8 | 44.7 | 11.6 | 52.8 |
| Alfalfa hay | 1924–25 | 18 | do | 4 | 84.81 | 10.2 | 45.4 | 12.1 | 53.5 |
| Alfalfa hay | 1924–25 | 22 | do | 2 | 85.34 | 10.1 | 46.2 | 11.8 | 54.1 |
| Average | | | | 8 | 84.89 | 10.1 | 45.4 | 11.9 | 53.5 |
| Sunflower silage | 1922–23 | 3 | Sheep | 3 | 26.18 | 1.4 | 13.0 | 5.3 | 49.7 |
| Sunflower silage | 1923–24 | 12 and 13 | Steers | 3 | 26.05 | 1.1 | 11.9 | 4.2 | 45.7 |
| Average | | | | 6 | 26.12 | 1.3 | 12.3 | 4.8 | 47.7 |
| Corn silage | 1922–23 | 4 | Sheep | 3 | 24.35 | 1.7 | 17.8 | 7.0 | 73.1 |
| Corn silage | 1923–24 | 15 | Steers | 2 | 30.47 | 1.3 | 20.0 | 4.3 | 65.6 |
| Corn silage | 1923–24 | 14 | do | 2 | 30.47 | 1.1 | 21.0 | 3.7 | 68.7 |
| Average | | | | 7 | 27.85 | 1.4 | 19.3 | 5.3 | 69.7 |
| Linseed meal [1] | 1923–24 | | Steers | 8 | 88.49 | 29.1 | 67.1 | 32.9 | 75.8 |
| Linseed meal [2] | | | | | 91.3 | 30.6 | 78.2 | 33.5 | 85.7 |
| Wild oats | 1924–25 | 21 | do | 2 | 88.07 | 8.5 | 54.2 | 9.6 | 61.6 |
| Oats, common [2] | | | | | 91.1 | 9.4 | 71.5 | 10.3 | 78.5 |

[1] Trials 9, 11, 12, and 17.
[2] Morrison (8).

From table 9 it is clear that the sweetclover-oat straw silage, trial 1, was decidedly lower in digestible protein and total digestible nutrients than the sweetclover silage made from the same crop, trial 2. Also, the table indicates clearly the importance of considering the dry-matter content of silages in making comparisons of nutritive values. The sweetclover silages fed in trials 2, 8, and 10 had approximately the same dry-matter content, digestible protein, and total digestible nutrients on the fresh basis. The silage fed in trial 20 contained 8 to 10 percent less dry matter and somewhat less total digestible nutrients than the three preceding silages, but, when compared on a dry-matter basis, this silage excelled the others in digestible protein and total digestible nutrients. Similarly, the corn silage fed in trial 4, because of its high water content, contained less digestible protein and total digestible nutrients than the corn silage fed in trials 14 and 15, but, on a dry-matter basis, it was really superior.

When compared on a dry-matter basis, the sweetclover silages and hays are similar to the alfalfa hays in nutritive values, but the sweetclover silages are, in general, a little higher in digestible protein and total digestible nutrients. Compared to the corn silages, the sweetclover silages are much higher in digestible crude protein, but lower in total digestible nutrients.

The sunflower silages contained about the same amounts of digestible crude protein as the corn silages, but in total digestible nutrients they were much lower than the corn, and considerably lower than the sweetclover silages. Of the three silages tested, the sunflowers were the least palatable and the lowest in nutritive value.

The corn silages used in these trials were made from Mercer flint corn. At corresponding stages of maturity and yields they have the same composition and nutritive values as silages from dent corn.

The mixing of oat straw with the sweetclover to reduce the moisture content of the silage and aid in its preservation proved unsatisfactory. The silage had a very strong odor and was less palatable than the straight sweetclover silage.

During a period of several years, sweetclover silage of good quality has been made at this station by allowing the sweetclover to wilt until it had a dry-matter content ranging from about 25 to 35 percent before ensiling it. By packing it thoroughly, the spoilage nas not been excessive and no evidences of so-called sweetclover poisoning have appeared. The digestion trials here reported indicate that when allowance is made for differences in water content, the sweetclover silages have essentially the same nutritive values as the green sweetclover or the cured hay, so far as digestibility is concerned. Unless weather conditions are ideal it is very difficult to make sweetclover hay which is free from mold. With unfavorable weather conditions for haymaking, the silo provides a means for storing the sweetclover in a safe and usable form. Sweetclover silage is not as palatable as corn silage; in fact it is usually necessary to reduce other feeds at first to induce stock to eat the silage. However, after becoming accustomed to it, they will eat it readily. In considering the value of sweetclover silage, its relatively high protein content is not to be ignored.

Our experience with the Russian sunflower indicates that it has no particular merit as a silage crop in this section. The sunflower silage is less palatable than the sweetclover silage.

The alfalfa hays fed in these trials represent good alfalfa hay in digestible crude protein and total digestible nutrients.

The digestible crude protein in the linseed meal on a dry basis is nearly the same as the value given by Morrison (*8*), but the total digestible nutrients are about 10 percent lower.

Since no values for wild oats have come to the authors' attention, the values given by Morrison for common oats are included in table 9 for comparison. Compared on a dry basis the wild oats contained nearly as much digestible crude protein as the common oats, but approximately 17 percent less of total digestible nutrients.

### AGE, LIVE WEIGHTS, AND DAILY NITROGEN BALANCES OF STEERS

The actual age of the steers was not known, and the ages given in table 10 are only approximate. The average live weights were computed from three to five weights on successive days, immediately

before and after the trials. As the feeds and excreta were weighed on scales graduated in pounds and decimals of pounds, the nitrogen balances are also expressed decimally in pounds. The nitrogen balances were determined primarily for the energy data.

TABLE 10.—*Age of steers, live weights, and daily nitrogen balances*

| Steer | Approximate age | Average live weight | Trial No. | Feeds | Nitrogen | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Feed | Feces | Urine | Balance |
| | *Months* | *Pounds* | | | *Pounds* | *Pounds* | *Pounds* | *Pounds* |
| A-22 | 21 | 902 | 8 | Sweet clover silage, early bloom | 0.3882 | 0.1153 | 0.2663 | +0.0066 |
| B-22 | 21 | 866 | | | .3923 | .1227 | .2572 | +.0124 |
| C-22 | 20 | 828 | 9 | Sweetclover silage, early bloom alfalfa and linseed meal. | .4583 | .1280 | .3066 | +.0237 |
| D-22 | 20 | 823 | | | .4331 | .1158 | .2953 | +.0220 |
| A-22 | 22 | 912 | 10 | Sweetclover silage, full bloom | .4256 | .1075 | .2309 | +.0872 |
| B-22 | 22 | 884 | | | .4464 | .1256 | .3516 | +.0308 |
| C-22 | 21 | 833 | 11 | Sweetclover silage, full bloom alfalfa and linseed meal. | .3768 | .0936 | .3057 | −.0225 |
| D-22 | 21 | 833 | | | .4125 | .1021 | .3238 | −.0134 |
| A-22 | 23 | 884 | 12 | Sunflower silage, alfalfa, and linseed meal. | .2716 | .0723 | .1897 | +.0096 |
| B-22 | 23 | 861 | | | .2716 | .0767 | .1925 | +.0024 |
| C-22 | 22 | 792 | 13 | Sunflower silage | .0820 | .0460 | .0547 | −.0187 |
| A-22 | 24 | 918 | 14 | Corn silage, alfalfa, and linseed meal | .2744 | .0908 | .1633 | +.0203 |
| B-22 | 24 | 877 | | | .2504 | .0844 | .1567 | +.0093 |
| C-22 | 23 | 788 | 15 | Corn silage | .1200 | .0543 | .0366 | +.0291 |
| D-22 | 23 | 807 | | | .1212 | .0663 | .0383 | +.0166 |
| A-22 | 25 | 882 | 16 | Alfalfa hay | .2513 | .0765 | .1982 | −.0234 |
| B-22 | 25 | 874 | | | .2513 | .0773 | .1741 | −.0001 |
| C-22 | 24 | 784 | 17 | Alfalfa hay and linseed meal | .2723 | .0648 | .1952 | +.0123 |
| D-22 | 24 | 801 | | | .2723 | .0714 | .2078 | −.0069 |
| A-24 | 7.5 | 467 | 18 | Alfalfa hay | .2329 | .0674 | .1391 | +.0264 |
| B-24 | 7.5 | 456 | | | .2329 | .0704 | .1605 | +.0020 |
| C-24 | 7.5 | 470 | | | .2329 | .0694 | .1378 | +.0257 |
| D-24 | 7.5 | 428 | | | .2096 | .0630 | .1401 | +.0065 |
| A-24 | 9.5 | 498 | 19 | Sweetclover, silage, alfalfa, and grain | .2833 | .0733 | .1782 | +.0318 |
| B-24 | 9.5 | 504 | | | .2833 | .0733 | .1743 | +.0357 |
| C-24 | 9.5 | 528 | | | .2833 | .0655 | .1771 | +.0407 |
| D-24 | 9.5 | 466 | | | .2833 | .0665 | .1763 | +.0405 |
| A-24 | 10.5 | 502 | 20 | Sweetclover silage | .2308 | .0469 | .1880 | −.0041 |
| B-24 | 10.5 | 513 | | | .2308 | .0472 | .1857 | −.0021 |
| C-24 | 10.5 | 530 | | | .2485 | .0512 | .2040 | −.0067 |
| D-24 | 10.5 | 484 | | | .2485 | .0507 | .2057 | −.0079 |
| A-24 | 11.5 | 571 | 21 | Alfalfa hay and wild oats | .2932 | .0831 | .1615 | +.0486 |
| B-24 | 11.5 | 579 | | | .3334 | .0977 | .1864 | +.0493 |
| C-24 | 11.5 | 583 | 22 | Alfalfa hay | .2891 | .0882 | .1865 | +.0234 |
| D-24 | 11.5 | 540 | | | .2981 | .0889 | .1855 | +.0237 |

## METABOLIZABLE ENERGY IN FEEDS AND RATIONS

The gross energy in the feed, feces, and urine was determined directly by means of a Parr adiabatic oxygen-bomb calorimeter. According to Armsby (*1*), 100 g of carbohydrates digested by ruminants produce 4.5 g of methane, with an energy value of 60.1 calories which is equivalent to 272.6 calories or 0.2726 therm per pound. The latter value was used in computing the energy value of the methane. The energy in the urine was corrected for gain or loss of protein by the steers by use of Rubner's value for protein nitrogen as employed by Armsby. The energy data on all the rations fed to steers are given in table 11.

Armsby (*1*) has shown that there is a rather striking uniformity in the metabolizable energy per unit of digestible organic matter in feeds and rations. He summarized the values found by various investigators and found that in 73 individual trials with cattle the metabolizable energy per pound of digestible organic matter in roughages ranged from 1.50 to 1.70 therms with an average of 1.60 therms. In 31 trials the values for concentrates ranged from 1.72 to 2.20 therms with an average of 1.83 therms, and in 76 trials the values for mixed rations ranged from 1.58 to 1.87 therms with an average of 1.66 therms.

TABLE 11.—*Gross energy of rations, losses in excreta, and metabolizable energy*

| Trial No. | Steer No. | Feeds | Energy in rations and excreta | | | | | | | | Metabolizable energy— | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Gross energy of feed | Losses | | | Metabolizable | Percentage losses of energy | | | Metabolizable | Per pound of digestible organic matter | Per pound of total digestible nutrients |
| | | | | In feces | In urine | As methane | | In feces | In urine | As methane | | | |
| | | | *Therms* | *Therms* | *Therms* | *Therms* | *Therms* | *Percent* | *Percent* | *Percent* | *Percent* | *Therms* | *Therms* |
| 8 | A–22 | Sweetclover silage, early bloom | 28.3683 | 11.895 | 2.332 | 1.412 | 12.731 | 41.93 | 8.22 | 4.98 | 44.88 | 1.782 | 1.711 |
| | B–22 | | 28.3655 | 11.976 | 2.307 | 1.407 | 12.675 | 42.22 | 8.13 | 4.96 | 44.69 | 1.787 | 1.712 |
| | | Average | | | | | | 42.08 | 8.18 | 4.97 | 44.79 | 1.785 | 1.712 |
| 10 | A–22 | Sweetclover silage, full bloom | 26.2439 | 10.318 | 2.725 | 1.298 | 11.903 | 39.32 | 10.38 | 4.94 | 45.36 | 1.718 | 1.664 |
| | B–22 | | 27.4549 | 11.975 | 2.442 | 1.264 | 11.773 | 43.62 | 8.89 | 4.61 | 42.88 | 1.731 | 1.682 |
| | | Average | | | | | | 41.47 | 9.64 | 4.78 | 44.12 | 1.725 | 1.673 |
| 20 | A–24, subperiod a | Sweetclover silage, early bloom | 13.6679 | 4.959 | 1.487 | .652 | 6.570 | 36.28 | 10.88 | 4.77 | 48.07 | 1.771 | 1.681 |
| | A–24, subperiod b | | 13.5029 | 4.894 | 1.370 | .651 | 6.588 | 36.24 | 10.15 | 4.82 | 48.79 | 1.786 | 1.693 |
| | B–24, subperiod a | | 13.6679 | 4.854 | 1.460 | .657 | 6.697 | 35.51 | 10.68 | 4.81 | 49.00 | 1.797 | 1.709 |
| | B–24, subperiod b | | 13.5029 | 4.822 | 1.380 | .654 | 6.647 | 35.71 | 10.22 | 4.84 | 49.23 | 1.794 | 1.694 |
| | C–24, subperiod a | | 14.7193 | 5.370 | 1.620 | .703 | 7.026 | 36.48 | 11.01 | 4.78 | 47.73 | 1.758 | 1.666 |
| | C–24, subperiod b | | 14.5934 | 5.378 | 1.563 | .694 | 6.958 | 36.85 | 10.71 | 4.76 | 47.68 | 1.765 | 1.671 |
| | D–24, subperiod a | | 14.7193 | 5.429 | 1.636 | .691 | 6.963 | 36.88 | 11.11 | 4.69 | 47.31 | 1.762 | 1.669 |
| | D–24, subperiod b | | 14.5934 | 5.185 | 1.469 | .706 | 7.233 | 35.53 | 10.07 | 4.84 | 49.56 | 1.810 | 1.715 |
| | | Average | | | | | | 36.19 | 10.60 | 4.79 | 48.42 | 1.780 | 1.687 |
| 8 | C–22 | Sunflower silage | 11.7719 | 6.414 | .441 | .615 | 4.302 | 54.49 | 3.74 | 5.22 | 36.55 | 1.670 | 1.596 |
| 15 | C–22 | Corn silage | 18.2490 | 5.748 | .735 | 1.436 | 10.330 | 31.50 | 4.03 | 7.87 | 56.60 | 1.755 | 1.681 |
| | D–22 | | 18.4339 | 6.821 | .684 | 1.352 | 9.577 | 37.00 | 3.71 | 7.33 | 51.96 | 1.740 | 1.664 |
| | | Average | | | | | | 34.25 | 3.87 | 7.60 | 54.28 | 1.747 | 1.673 |
| 16 | A–22 | Alfalfa hay | 18.8765 | 8.281 | 1.127 | 1.053 | 8.415 | 43.87 | 5.97 | 5.58 | 44.58 | 1.694 | 1.688 |
| | B–22 | | 18.8765 | 8.360 | 1.021 | 1.052 | 8.443 | 44.29 | 5.41 | 5.57 | 44.73 | 1.706 | 1.704 |
| | | Average | | | | | | 44.08 | 5.69 | 5.58 | 44.66 | 1.700 | 1.696 |
| 18 | A–24 | Alfalfa hay | 16.9398 | 7.637 | .960 | .904 | 7.439 | 45.08 | 5.67 | 5.34 | 43.92 | 1.684 | 1.652 |
| | B–24 | | 16.9398 | 7.612 | .959 | .918 | 7.451 | 44.94 | 5.66 | 5.42 | 43.98 | 1.671 | 1.637 |
| | C–24 | | 16.9398 | 7.474 | .938 | .936 | 7.593 | 44.12 | 5.53 | 5.53 | 44.82 | 1.680 | 1.651 |
| | D–24 | | 15.2458 | 6.897 | .877 | .818 | 6.654 | 45.24 | 5.75 | 5.37 | 43.65 | 1.674 | 1.643 |
| | | Average | | | | | | 44.85 | 5.65 | 5.42 | 44.09 | 1.677 | 1.646 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | C–24, subperiod a | Alfalfa hay | 22.4014 | 9.318 | 1.287 | 1.290 | 10.506 | 41.59 | 5.75 | 5.76 | 46.90 | 1.720 | 1.709 |
| | C–24, subperiod b | | 22.4014 | 9.704 | 1.258 | 1.236 | 10.204 | 43.32 | 5.61 | 5.52 | 45.55 | 1.730 | 1.709 |
| | D–24, subperiod a | | 22.4014 | 9.835 | 1.259 | 1.233 | 10.075 | 43.90 | 5.62 | 5.50 | 44.97 | 1.712 | 1.694 |
| | D–24, subperiod b | | 22.4014 | 9.838 | 1.231 | 1.232 | 10.100 | 43.92 | 4.39 | 5.50 | 45.09 | 1.722 | 1.705 |
| | | Average | | | | | | 43.18 | 5.34 | 5.57 | 45.63 | 1.721 | 1.702 |
| 9 | C–22 | Sweetclover, early bloom, alfalfa hay, linseed meal | 29.6747 | 12.219 | 2.242 | 1.458 | 13.755 | 41.18 | 7.56 | 4.91 | 46.35 | 1.791 | 1.715 |
| | D–22 | | 27.8976 | 11.345 | 2.132 | 1.378 | 13.042 | 40.67 | 7.64 | 4.94 | 46.75 | 1.785 | 1.707 |
| | | Average | | | | | | 40.93 | 7.60 | 4.93 | 46.55 | 1.788 | 1.711 |
| 11 | C–22 | Sweetclover silage, full bloom, alfalfa hay, linseed meal | 22.1523 | 8.873 | 1.754 | 1.084 | 10.442 | 40.05 | 7.92 | 4.89 | 47.14 | 1.754 | 1.681 |
| | D–22 | | 23.9586 | 9.632 | 1.950 | 1.143 | 11.233 | 40.20 | 8.14 | 4.77 | 46.89 | 1.767 | 1.692 |
| | | Average | | | | | | 40.13 | 8.03 | 4.83 | 47.02 | 1.761 | 1.687 |
| 19 | A–24, subperiod a | Sweetclover silage, early bloom, alfalfa hay, grain mixture [1] | 18.5901 | 6.864 | 1.338 | 1.074 | 9.314 | 36.92 | 7.20 | 5.78 | 50.10 | 1.727 | 1.664 |
| | A–24, subperiod b | | 18.6343 | 6.557 | 1.395 | 1.103 | 9.579 | 35.19 | 7.49 | 5.92 | 51.41 | 1.725 | 1.661 |
| | B–24, subperiod a | | 18.5901 | 6.544 | 1.320 | 1.110 | 9.616 | 35.20 | 7.10 | 5.97 | 51.73 | 1.736 | 1.668 |
| | B–24, subperiod b | | 18.6343 | 6.456 | 1.396 | 1.114 | 9.668 | 34.65 | 7.49 | 5.98 | 51.88 | 1.724 | 1.656 |
| | C–24, subperiod a | | 18.5901 | 6.444 | [2] | 1.114 | [2] | 34.66 | [2] | 5.99 | [2] | [2] | [2] |
| | C–24, subperiod b | | 18.6343 | 6.126 | 1.420 | 1.137 | 9.951 | 32.87 | 7.62 | 6.10 | 53.40 | 1.733 | 1.668 |
| | D–24, subperiod a | | 18.5901 | 6.313 | 1.389 | 1.123 | 9.765 | 33.96 | 7.47 | 6.04 | 52.53 | 1.733 | 1.664 |
| | D–24, subperiod b | | 18.6343 | 6.451 | 1.432 | 1.108 | 9.643 | 34.62 | 7.68 | 5.95 | 51.75 | 1.717 | 1.651 |
| | | Average | | | | | | 34.76 | 7.44 | 5.97 | 51.83 | 1.728 | 1.662 |
| 12 | A–22 | Sunflower silage, alfalfa hay, linseed meal | 19.3085 | 8.165 | 1.079 | .981 | 9.085 | 42.28 | 5.59 | 5.08 | 47.05 | 1.802 | 1.718 |
| | B–22 | | 19.3085 | 8.135 | 1.085 | .998 | 9.090 | 42.13 | 5.62 | 5.17 | 47.08 | 1.792 | 1.710 |
| | | Average | | | | | | 42.21 | 5.61 | 5.13 | 47.07 | 1.797 | 1.714 |
| 14 | A–22 | Corn silage, alfalfa hay, linseed meal | 23.6947 | 8.198 | 1.278 | 1.606 | 12.613 | 34.60 | 5.39 | 6.78 | 53.23 | 1.731 | 1.660 |
| | B–22 | | 21.3615 | 7.834 | 1.177 | 1.379 | 10.972 | 36.67 | 5.51 | 6.46 | 51.36 | 1.732 | 1.653 |
| | | Average | | | | | | 35.64 | 5.45 | 6.62 | 52.30 | 1.732 | 1.657 |
| 17 | C–22 | Alfalfa hay, linseed meal | 15.9872 | 6.316 | 1.099 | .800 | 7.772 | 39.51 | 6.88 | 5.00 | 48.61 | 1.786 | 1.727 |
| | D–22 | | 15.9872 | 6.946 | 1.027 | .746 | 7.268 | 43.45 | 6.43 | 4.67 | 45.46 | 1.771 | 1.712 |
| | | Average | | | | | | 41.48 | 6.66 | 4.84 | 47.04 | 1.779 | 1.720 |
| 19 | A–24, subperiod a | Alfalfa hay, wild oats | 25.7809 | 10.384 | 1.145 | 1.461 | 12.790 | 40.28 | 4.44 | 5.67 | 49.61 | 1.809 | 1.688 |
| | A–24, subperiod b | | 25.8583 | 9.966 | 1.135 | 1.501 | 13.238 | 38.54 | 4.39 | 5.80 | 51.19 | 1.834 | 1.745 |
| | B–24, subperiod a | | 28.8652 | 11.852 | 1.263 | 1.592 | 14.158 | 41.06 | 4.38 | 5.52 | 49.05 | 1.826 | 1.706 |
| | B–24, subperiod b | | 28.8652 | 11.758 | 1.253 | 1.594 | 14.260 | 40.74 | 4.34 | 5.52 | 49.40 | 1.840 | 1.720 |
| | | Average | | | | | | 40.15 | 4.39 | 5.63 | 49.81 | 1.827 | 1.715 |

[1] Ground barley, 3 parts; linseed meal, 1 part.
[2] Energy determination not made; sample lost.

The metabolizable energy per pound of digestible organic matter as given in table 11 ranges from 1.67 to 1.81 therms for the roughages and from 1.72 to 1.84 therms for the mixed rations. The average of 25 trials is 1.737 therms for the roughages and 1.767 therms for 21 trials on mixed rations. These values are a little higher than the averages found by Armsby.

No determinations of metabolizable energy on sweetclover or sunflower silages have come to the authors' attention, but in a single determination on corn silage Forbes and associates (*3*) found 1.731 therms per pound of digestible organic matter compared to the value herein given of 1.747 therms.

The metabolizable energy per pound of total digestible nutrients ranges from 1.60 to 1.72 therms for the roughages and from 1.65 to 1.75 therms for the mixed rations. The average for the roughages is 1.670 therms and for the mixed rations, 1.689 therms or an average of 1.744 therms for the 46 trials. Forbes and Kriss found a somewhat lower value, namely; 1 pound of total digestible nutrients equivalent to 1.616 therms of metabolizable energy, according to an editorial review by Kriss (*6*).

## METABOLIZABLE ENERGY IN FEEDS AND FEED MIXTURES, COMPUTED INDIRECTLY

The metabolizable energy per pound of digestible organic matter was computed indirectly for some feeds and feed mixtures similarly to the computations of digestibility. The computation of the metabolizable energy of linseed meal, trial 9, steer C–22, will serve to illustrate the method employed. The data of table 5, when corrected for an air-dry sweetclover residue of 0.263 pound, equivalent to 0.73 pound of fresh silage, show that steer C–22 consumed 24.27 pounds of sweetclover silage containing 7.379 pounds of organic matter having a digestibility of 58.6 percent, trial 8 (table 7), or 4.324 pounds of digestible organic matter. Similarly, it is found that the 5 pounds of alfalfa hay eaten contained 2.226 pounds of digestible organic matter. The digestible organic matter in the whole ration was 7.682 pounds. Subtracting the organic matter of the silage and alfalfa from the total gives 1.132 pounds of digestible organic matter in the linseed meal.

The metabolizable energy per pound of digestible organic matter in the silage was determined as 1.785 therms, trial 8, and for the alfalfa hay as 1.700 therms, trial 16 (table 11). Multiplying the digestible organic matter of the silage and alfalfa by their respective values, and adding, gives 11.502 therms of metabolizable energy in the silage and alfalfa. Deducting this from 13.755 therms of metabolizable energy in the total ration (table 11) leaves 2.253 therms of metabolizable energy in the 1.132 pounds of digestible organic matter in the linseed meal eaten or 1.99 therms per pound of digestible organic matter. The results of these computations are summarized in table 12.

TABLE 12.—*Metabolizable energy per pound of digestible organic matter and per pound of total digestible nutrients in feeds and feed mixtures, computed indirectly*

| Feeds | Individual trials | Metabolizable energy | | | |
|---|---|---|---|---|---|
| | | Per pound of digestible organic matter | | | Per pound of total digestible nutrients |
| | | Maximum | Minimum | Average | |
| | *Number* | *Therms* | *Therms* | *Therms* | *Therms* |
| Linseed meal, all trials | 10 | 2.19 | 1.70 | 1.97 | 1.72 |
| Linseed meal, omitting trial 14 [1] | 8 | 2.19 | 1.93 | 2.03 | 1.74 |
| Barley 3 parts; linseed meal 1 part | 7 | 1.72 | 1.68 | 1.70 | 1.62 |
| Wild oats | 2 | 1.95 | 1.88 | 1.92 | 1.86 |
| Alfalfa 5 parts; linseed meal 2 parts | 4 | 1.80 | 1.77 | 1.79 | 1.71 |
| Sunflower silage | 2 | 1.83 | 1.78 | 1.81 | 1.70 |

[1] As steers A-22 and B-22, trial 14, gave considerably lower values, 1.74 and 1.70 therms per pound of digestible organic matter, respecitvely, this summary with these steers omitted is given.

Armsby (*1*) gives values of 1.996 to 2.177 therms per pound of digestible organic matter in oil meals and materials high in protein. The values in table 12 agree with the lower values given by Armsby. The average value for barley 3 parts and linseed meal 1 part is close to the values directly determined for the roughages and mixed rations, but is slightly lower. The value for the wild oats seems too high, but no reason can be given for this. The value for alfalfa 5 parts and linseed meal 2 parts is 1.79 therms, which is similar to the values obtained for mixed rations and is practically identical with the directly determined value of 1.779 therms for alfalfa hay 7 parts and linseed meal 2 parts (table 11), trial 17. The indirectly computed value for the sunflower silage is 1.81 therms compared to the single directly determined value of 1.67 therms (table 11), trial 13. The directly determined value for the sunflower silage is lower than the value for the other silages, but the indirectly computed values are higher. The differences between the directly determined and the computed values are undoubtedly due, at least in part, to applying the values obtained with one set of steers on a single feed to the data obtained with other steers on mixed rations. However, the data in general confirm Armsby's observations on the uniformity of metabolizable energy in feeds per unit of digestible organic matter.

## SUMMARY

In composition the silages made from sweetclover, sunflowers, and corn were generally higher in ash, crude protein, crude fiber, and ether extract, but lower in nitrogen-free extract than the crops when ensiled. The protein nitrogen ranged from 57.02 to 86.19 percent of the total nitrogen in the crops when ensiled and from 34.50 to 60.75 percent in the silages.

Compared on a dry-matter basis, the sweetclover silages and hays resembled alfalfa hay in percentage of digestibility, digestible nutrients, and metabolizable energy; but the sweetclover silages averaged a little higher in digestible crude protein and total digestible nutrients. Mixing 1 part of dry oat straw with 5.5 parts of green sweetclover reduced the digestible crude protein 56 percent and total digestible nutrients 37 percent in the silage, on dry basis, as compared to the straight sweetclover silage from the same crop (table 9).

On a dry basis (table 9), the straight sweetclover silage contained an average of 16.2 percent of digestible protein and 56.8 percent of

total digestible nutrients, compared to 5.3 percent of digestible protein and 69.7 percent of total digestible nutrients in the corn silage. The sunflower silage contained 4.8 percent of digestible protein and 47.7 percent of total digestible nutrients.

The sunflower silages were less palatable than the sweetclover silages, and the sweetclover silages were less palatable than the corn silages.

The linseed meal, dry basis, contained 32.9 percent of digestible protein and 75.8 percent of total digestible nutrients, compared to Morrison's (*8*) averages of 33.5 and 85.7 percent, respectively, for old process linseed meal.

The wild oats, dry basis, contained 9.6 percent of digestible protein and 61.6 percent of total digestible nutrients, compared to Morrison's averages of 10.3 and 78.5 percent, respectively, for common oats.

The metabolizable energy per pound of digestible organic matter in the different feeds and rations was fairly uniform. The average of 25 individual determinations on roughages was 1.737 therms per pound and 1.767 therms for 21 mixed rations, compared to 1.60 therms for roughages and 1.66 therms for mixed rations, as given by Armsby (*1*). The computed values for linseed meal and other concentrates are similar to Armsby's values.

In 25 individual trials the average metabolizable energy per pound of total digestible nutrients was 1.670 therms, and in 21 trials on mixed rations, it was 1.689 therms.

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# THE RELATION OF COLOR AND CAROTENE CONTENT OF ROUGHAGE IN THE DAIRY RATION TO THE COLOR, CAROTENE CONTENT, AND VITAMIN A ACTIVITY OF BUTTERFAT [1]

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## INTRODUCTION AND REVIEW OF LITERATURE

In western Washington the majority of the pastures remain green and the grasses grow fairly rapidly throughout the summer. This insures a relatively high carotene consumption by dairy cows during the summer. In the winter, however, much of the hay fed is of inferior quality and of poor color and low carotene content, even though it is made from material originally high in color and carotene.

It is evident from research by Meigs and Converse (*15*),[3] Hart and Guilbert (*9*), and Guilbert and Hart (*8*) that dairy cattle require vitamin A or carotene in the ration for the purpose of sustaining normal health, growth, and reproduction. Kennedy and Dutcher (*13*) were among the first to report that the vitamin A value of milk is influenced by the vitamin A value of the feed, an observation which has since been confirmed by numerous investigators.

Moore (*17*) has shown that the cow converts carotene into vitamin A. The vitamin A activity of roughage in general has been shown to be related to its carotene content. Guilbert (*7*) has used the carotene analysis as a measure of vitamin A activity.

Since the roughage part of the dairy ration is the principal source of the carotene or vitamin A factor, farmers must guard against destruction of the carotene in providing roughages for their herds. Krauss (*14*), Watson (*26*), and others have shown that pasture is potent in the vitamin A factor and produces a milk of high vitamin A activity. The carotene content of roughages may vary considerably. Some of the more important factors causing variations in carotene content or in vitamin A activity are stage of maturity (*4, 12*), method of drying (*10, 20*), variety of plant (*11, 15*), and storage (*5*).

Russell and associates (*21*) and others have shown that silage may be a good source of vitamin A in the dairy ration. Peterson and coworkers (*19*) reported that the feeding of A. I. V. silage to cows produced a materially higher carotene and vitamin A content in the milk than did a check ration containing no silage.

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[3] Italic numbers in parentheses refer to Literature Cited, p. 527.

Graves and associates (*6*) observed a relationship between the green color of hay and the color of the butterfat, while Converse, Wiseman, and Meigs (*3*) state that the color of butterfat varies definitely with the green color and the carotene content of the roughage fed.

The work herein reported was undertaken to determine the carotene content of feeds similar to those generally fed to dairy herds in this section and its relation to the color, carotene content, and vitamin A activity of the butterfat produced by cows receiving rations consisting exclusively of these feeds.

## EXPERIMENTAL PROCEDURE

The roughage feeds studied in these experiments were pasture grass (grazed), field-cured hay made from perennial grass and clover mixtures, silage made from the grass and clover mixtures, and silage made from oats and peas.

When a crop was to be made into hay, it was cut after the dew had dried off and was allowed to lie in the windrow until thoroughly wilted after which it was raked and cocked. The hay remained in the cock until it was dry enough to be stored in the barn. Rain sometimes made it necessary to turn the cocks to facilitate drying. The method of making hay approximated the farm practices in this section.

The first year the forage made into silage was allowed to wilt before it was put into the silo. The second year ensiling was begun immediately after the forage was cut. Silage was made both in the ordinary upright silo and in the "stack" silo.

Thirty Holstein-Friesian cows that were being used in a general investigation of the nutritive value of home-grown all-roughage rations were being fed the roughages studied in these experiments. In the winter one group of 10 cows was maintained on the hay, a second group of 10 cows was maintained on the silage, and a third group of 10 cows was fed a ration containing both hay and silage. In the summer all three groups were maintained on pasture alone. No supplements other than salt and iodine were fed.

The crops from which the samples of roughage were taken and analyzed for their carotene and color content were grown in 1934 and 1935, and fed during 1934, 1935, and 1936. Each summer three samples of pasture grass were obtained at approximately 14-day intervals. In 1934, the first sample was taken May 24 and in 1935, on June 26. During the two winter feeding periods the hay and silage samples were also taken at approximately 14-day intervals, at the time of feeding, and represented the regular ration as it came from the haymow or from the silos. In 1934, the first samples were taken on December 14 and in 1935, on December 27. Each year the cows were receiving hay or silage rations at least 90 days before the samples were taken.

Carotene and color analyses were made on samples of the butterfat produced by cows receiving the various roughages. The butterfat samples were obtained from the evening's milk on the day the feed samples were taken and from the following morning's milk. The milk from each group was from cows in different stages of lactation. The milk was separated while still warm and the cream from the evening's and morning's milk was combined. The sweet cream was churned in a small churn at a temperature of 10° to 15° C. The

freshly churned butter was melted at 60°, centrifuged, and the pure fat decanted into glass containers. These samples were analyzed for carotene and color and fed to rats to determine their vitamin A value.

All samples of feed and butterfat were frozen as soon after they were taken as possible. The samples were packed in solid carbon dioxide and held in it, or at −20° C. or below, until prepared for analysis.

Carotene determinations were made on duplicate samples of the feed by a modification of the methods of Schertz (*22*) and Miller (*16*). The first extraction of the pigments was made by grinding the samples in a ball mill from which the air was excluded with carbon dioxide. The samples were covered with acetone during the grinding and the apparatus was kept at 0° C. throughout the process. After the samples were ground the extractions were completed with acetone and ether. The pigment concentration, after fractionation, was determined by means of an Exton-photoelectric scopometer previously calibrated with pure beta-carotene. The pigments were extracted from the butterfat with ethyl ether after saponification. The pigments were then fractionated and determined in the same manner as for the feeds. The color determinations both of the feed and the butterfat were made by the Bureau of Agricultural Economics, United States Department of Agriculture according to the method described by Nickerson (*18*).

Three experiments were run to determine the vitamin A value of the butterfat. Experiment 1 was conducted in the winter of 1934 on samples of butterfat produced by cows on the hay alone, on the silage alone, and on the hay and silage. Experiment 2 was conducted in the summer of 1935 on samples of butterfat produced by cows on pasture. Experiment 3 was conducted in the winter of 1935, and duplicated experiment 1.

Determinations of the vitamin A value of the butterfat samples were made by a modified Sherman (*24*) technique, as follows: Young albino rats from mothers receiving a diet with a standardized vitamin A content were used in each experiment. After 21 days of age they were maintained on a vitamin A-free diet consisting of heated casein, 18 percent; dry yeast, 10 percent; Osborne and Mendel salt mixture, 4 percent; sodium chloride, 1 percent; and heated cornstarch, 67 percent. The casein was heated for 108 hours at 105° C. Vitamin D was supplied by the addition of 0.02 percent of 250 D viosterol. When the animals were depleted of their body stores of vitamin A, as indicated by a stationary or declining weight for 4 consecutive days, they were placed in individual cages and the basal ration was supplemented with a butterfat sample, fed twice a week over a period of 5 weeks. The butterfat was fed on watch crystals. The rats were distributed among the various groups according to the suggestions of Sherman and Burtis (*23*). With each experiment a representative group of rats was maintained on the basal diet as a negative control.

In the second and third experiments the technique was modified to include in each experiment two representative groups of rats which received supplements of the U. S. P. x (1934) reference cod-liver oil (*25*) containing 3,000 units of vitamin A per gram, mixed in coconut oil. The reference oil was given twice a week directly into the mouth by means of a syringe. In each experiment, one lot was fed at the

rate of 1.43 and the other at the rate of 2.00 units of vitamin A per day. The reference mixtures were made up every 10 days and were held in a refrigerator between feeding periods.

## EXPERIMENTAL RESULTS

Six samples of pasture grass, and 12 samples each of the hay ration, of the silage ration, and of the hay and silage ration, were available for study of the realtion between the carotene content of the feeds and the color and carotene of the butterfat.

Pasture grass sample Nos. 1, 2, and 3 were obtained during 1934 and Nos. 4, 5, and 6 during 1935. Hay or silage samples 1 to 5, inclusive, represent the 1934 crop and samples 6 to 12, inclusive, represent the 1935 crop. Sample Nos. 4 and 5 and 11 and 12 were silage made from oats and peas, the remainder being silage made from the same type of material as was the hay.

Color measurements for roughage were made only for the hay. The relationship of these various factors in the feed and butterfat is shown in table 1, the feed samples in each ration being arranged according to their carotene content, in descending order from the lowest to the highest.

There appears to be a general relationship between the green color of the hay and its carotene content, that is, the higher the color the higher the carotene content, but the relationship between these factors was not consistent.

In none of the rations was there a consistent relationship between the carotene content of the feed sample and that of the butterfat, nor between the carotene content of the butterfat and its color.

TABLE 1.—*Relation of the color and carotene content of roughage to the color and carotene content of butterfat produced by cows on the different rations*

HOME-GROWN HAY

| Sample No.[1] | Roughage | | Butterfat | |
|---|---|---|---|---|
| | Color [2] | Carotene content per gram (dry-matter basis) | Carotene content per gram (dry-matter basis) | Color index chroma reading |
| | *Percent* | *Micrograms* | *Micrograms* | |
| 4 | 34 | 8 | 2.6 | 4.7 |
| 5 | 39 | 9 | 2.8 | 3.9 |
| 2 | 32 | 12 | 2.8 | 5.0 |
| 1 | 41 | 12 | 3.0 | 4.3 |
| 3 | 40 | 13 | 3.0 | 4.2 |
| 7 | 52 | 16 | 4.5 | 4.9 |
| 9 | 60 | 17 | 4.3 | 4.4 |
| 10 | 59 | 17 | 4.2 | 5.5 |
| 11 | 53 | 18 | 3.6 | 5.0 |
| 6 | 52 | 18 | 4.5 | 4.6 |
| 8 | 46 | 19 | 3.7 | 4.6 |
| 12 | 55 | 19 | 3.6 | 4.6 |
| Mean | | 14.8 | 3.55 | 4.64 |

[1] Sample numbers represent the order in which the feeds were fed. In the hay, hay and silage, and silage ration samples 1 to 5, inclusive, represent the 1934 crop and samples 6 to 12, inclusive, represent the 1935 crop. Pasture samples 1, 2, and 3 were taken in 1934, and 4, 5, and 6 in 1935.

[2] Indicates percentage of the natural green color.

TABLE 1.—*Relation of the color and carotene content of roughage to the color and carotene content of butterfat produced by cows on the different rations*—Continued

HAY AND SILAGE

| Sample No. | Roughage | | Butterfat | |
|---|---|---|---|---|
| | Color | Carotene content per gram (dry-matter basis) | Carotene content per gram (dry-matter basis) | Color index chroma reading |
| | *Percent* | *Micrograms* | *Micrograms* | |
| 10 | | 31 | 7.3 | 6.1 |
| 11 | | 41 | 5.6 | 5.9 |
| 9 | | 43 | 7.2 | 5.2 |
| 8 | | 45 | 7.5 | 5.9 |
| 12 | | 49 | 5.9 | 5.8 |
| 7 | | 50 | 8.0 | 6.1 |
| 4 | | 54 | 6.0 | 5.3 |
| 1 | | 56 | 6.0 | 5.2 |
| 2 | | 58 | 6.0 | 5.8 |
| 5 | | 75 | 5.9 | 5.3 |
| 6 | | 87 | 7.9 | 6.0 |
| 3 | | 95 | 5.2 | 5.3 |
| Mean | | 57.0 | 6.54 | 5.66 |

SILAGE

| | | | | |
|---|---|---|---|---|
| 1 | | 107 | 6.4 | 5.7 |
| 4 | | 109 | 6.5 | 5.6 |
| 2 | | 134 | 6.4 | 5.8 |
| 5 | | 156 | 6.0 | 6.0 |
| 10 | | 157 | 7.5 | 6.2 |
| 3 | | 199 | 5.1 | 5.0 |
| 11 | | 205 | 6.8 | 5.5 |
| 9 | | 233 | 6.7 | 5.7 |
| 8 | | 251 | 6.1 | 5.8 |
| 12 | | 260 | 7.2 | 6.0 |
| 7 | | 268 | 8.2 | 5.8 |
| 6 | | 288 | 8.3 | 6.3 |
| Mean | | 197.3 | 6.77 | 5.78 |

PASTURE

| | | | | |
|---|---|---|---|---|
| 2 | | 220 | 7.4 | 6.0 |
| 3 | | 256 | 7.6 | 5.4 |
| 6 | | 258 | 9.1 | 6.0 |
| 1 | | 266 | 6.5 | 5.9 |
| 5 | | 273 | 8.1 | 5.8 |
| 4 | | 286 | 8.7 | 5.7 |
| Mean | | 260.0 | 7.9 | 5.8 |

Comparison of the average values, however, shows that as the carotene content of the ration increased there was an increase in the carotene and color of the butterfat. The increase in the butterfat was not in direct proportion to the increase in the ration, however. The average carotene content of the pasture grass was 17.6 times as high as that of the hay ration; the silage was 13.3 times as high; and the hay and silage was 3.8 times as high; whereas the carotene content of the butterfat produced on pasture, on silage, and on hay and silage, was only 2.2, 1.9, and 1.8 times as high, respectively, as that produced on hay.

The relation between the carotene content and color of the 42 samples of butterfat is shown graphically in figure 1. The spread in color index of the butterfat, from the high to the low, is not so great as the spread in carotene content.

A summary of the observations during the 2-year experimental feeding period shows the relative effectiveness of the different kinds of roughage in producing butterfat with a high carotene content, when fed as the sole ration. Considering the effectiveness of the home-grown field-cured hay as 1.00, the comparative results were as follows:

| Roughage, and its treatment: | *Relative carotene value of the butterfat* |
|---|---|
| Hay, home-grown, field-cured | 1.00 |
| Hay, plus oat and pea silage (silo) | 1.75 |
| Grass silage (silo) | 1.88 |
| Hay, plus grass silage (silo) | 1.90 |
| Oat and pea silage (silo) | 1.99 |
| Hay, plus grass silage (stack) | 2.00 |
| Grass silage (stack) | 2.07 |
| Pasture grass (grazed) | 2.22 |

Although in many instances the hay and the grass silage were made from the same type of crop material, harvested at approximately the same time, the hay contained much less carotene than the silage. This would indicate that the haymaking and hay-storing practices were very destructive to carotene. The high carotene content of the silages studied would appear to indicate that ensiling a crop is an effective way to produce feeds of high carotene content for winter feeding.

From the data at hand it is possible to calculate the percentage of ingested carotene that was transmitted to the butterfat unchanged. Table 2 shows the average daily carotene intake by the cows on the hay ration, the silage ration, and the hay and silage ration, also the percentage of the carotene intake that was recovered as such in the butterfat.

On an average, the higher the daily carotene intake the lower the percentage of the intake that is transmitted unchanged to the butterfat. Furthermore, at any level of carotene intake the percentage transmitted is very small. Even in the hay ration, in which the average daily consumption of carotene was as low as 147 mg per day (see 1934 trials, table 2), the percentage transmitted was less than 1 percent. The average carotene content of both the hay and silage was much less in 1934 than in 1935. The percentages of ingested carotene transmitted unchanged to the butterfat, indicated by this study, while somewhat lower than the percentages reported by Baumann and associates (*1*), tend to confirm their results.

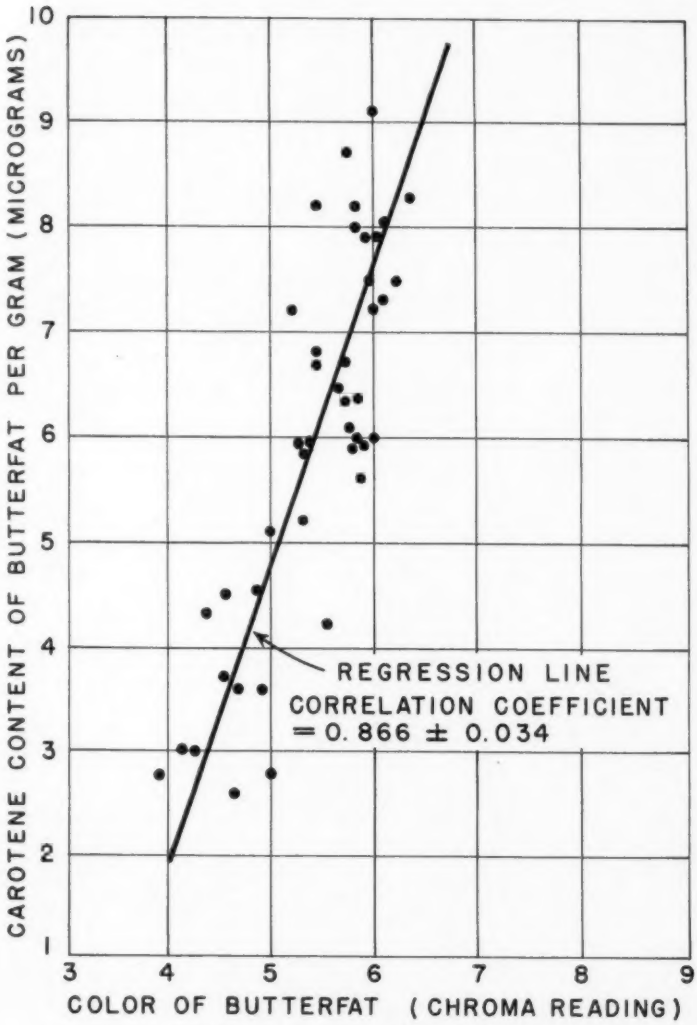


FIGURE 1.—Relation of carotene content of butterfat to its color.

TABLE 2.—*Average daily consumption of carotene per cow on rations of hay alone, hay and silage, and silage alone (dry-matter basis); also the percentage of the carotene intake that was recovered as such in the butterfat*

| Crop year, and sample No. | Cows | Hay | | | Silage | | | Total carotene intake | Butterfat | | | Percentage of the carotene intake recovered in the butterfat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Quantity fed | Carotene content per gram | Carotene consumed | Quantity fed | Carotene content per gram | Carotene consumed | | Yield | Carotene content per gram | Total carotene | |
| **HAY RATION** | | | | | | | | | | | | |
| 1934: | *Number* | *Kilograms* | *Micrograms* | *Milligrams* | *Kilograms* | *Micrograms* | *Milligrams* | *Milligrams* | *Kilograms* | *Micrograms* | *Milligrams* | *Percent* |
| 1 | 5 | 13.11 | 12.4 | 162.5 | | | | 162.5 | 0.368 | 3.1 | 1.14 | 0.70 |
| 2 | 5 | 13.52 | 12.2 | 164.9 | | | | 164.9 | .430 | 2.8 | 1.20 | .73 |
| 3 | 5 | 13.65 | 13.2 | 180.1 | | | | 180.1 | .410 | 3.0 | 1.23 | .67 |
| 4 | 5 | 13.38 | 7.6 | 101.7 | | | | 101.7 | .381 | 2.6 | .99 | .97 |
| 5 | 5 | 13.47 | 9.4 | 126.6 | | | | 126.6 | .313 | 2.8 | .88 | .69 |
| Average | 5 | 13.43 | 11.0 | 147.2 | | | | 147.2 | .380 | 2.9 | 1.09 | 1.74 |
| 1935: | | | | | | | | | | | | |
| 6 | 8 | 12.16 | 18.0 | 218.8 | | | | 218.8 | .364 | 4.5 | 1.64 | .75 |
| 7 | 8 | 12.16 | 16.0 | 194.5 | | | | 194.5 | .364 | 4.5 | 1.64 | .84 |
| 8 | 9 | 11.79 | 19.0 | 224.0 | | | | 224.0 | .408 | 3.7 | 1.51 | .67 |
| 9 | 9 | 11.93 | 17.0 | 202.8 | | | | 202.8 | .381 | 4.3 | 1.64 | .81 |
| 10 | 10 | 11.88 | 17.0 | 202.0 | | | | 202.0 | .335 | 4.2 | 1.41 | .70 |
| 11 | 9 | 11.16 | 18.0 | 200.9 | | | | 200.9 | .313 | 3.6 | 1.13 | .56 |
| 12 | 8 | 12.79 | 19.0 | 243.1 | | | | 243.1 | .352 | 3.6 | 1.27 | .52 |
| Average | 8.7 | 11.98 | 17.7 | 212.3 | | | | 212.3 | .360 | 4.1 | 1.46 | 1.69 |
| Grand average | 7.2 | 12.58 | 14.9 | 185.2 | | | | 185.2 | .368 | 3.6 | 1.31 | 1.71 |
| **HAY AND SILAGE RATION** | | | | | | | | | | | | |
| 1934: | | | | | | | | | | | | |
| 1 | 7 | 6.35 | 12.4 | 78.7 | 5.31 | 107 | 567.1 | 645.8 | 0.386 | 6.0 | 2.32 | 0.36 |
| 2 | 7 | 6.67 | 12.2 | 81.4 | 4.04 | 134 | 541.4 | 617.4 | .344 | 6.0 | 2.06 | .34 |
| 3 | 7 | 6.85 | 13.2 | 90.4 | 5.22 | 199 | 1,038.8 | 1,125.0 | .310 | 5.2 | 1.61 | .14 |
| 4 | 7 | 6.49 | 7.6 | 49.3 | 5.53 | 109 | 603.9 | 648.8 | .297 | 6.0 | 1.78 | .27 |
| 5 | 6 | 6.40 | 9.4 | 60.1 | 4.76 | 156 | 742.6 | 808.9 | .274 | 5.9 | 1.62 | .20 |
| Average | 6.8 | 6.55 | 11.0 | 72.0 | 4.97 | 141 | 698.8 | 770.8 | .322 | 5.8 | 1.88 | 1.24 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1935: | | | | | | | | | | | | |
| 6 | 9 | 7.57 | 18.0 | 136.3 | 4.63 | 288 | 1,333.4 | 1,461.1 | .338 | 7.9 | 2.67 | .18 |
| 7 | 9 | 7.57 | 16.0 | 121.1 | 4.63 | 268 | 1,240.8 | 1,353.9 | .338 | 8.0 | 2.70 | .20 |
| 8 | 10 | 7.53 | 19.0 | 143.1 | 3.99 | 251 | 1,001.5 | 1,147.1 | .369 | 7.5 | 2.77 | .24 |
| 9 | 10 | 7.57 | 17.0 | 128.7 | 4.26 | 233 | 992.6 | 1,130.6 | .350 | 7.2 | 2.52 | .22 |
| 10 | 9 | 7.98 | 17.0 | 135.7 | 4.54 | 157 | 712.8 | 842.2 | .348 | 7.3 | 2.54 | .30 |
| 11 | 8 | 6.89 | 18.0 | 124.0 | 4.40 | 205 | 902.0 | 1,026.0 | .327 | 5.6 | 1.83 | .18 |
| 12 | 8 | 7.12 | 19.0 | 135.3 | 4.17 | 260 | 1,084.2 | 1,227.3 | .323 | 5.9 | 1.91 | .16 |
| Average | 9 | 7.46 | 17.7 | 132.0 | 4.37 | 237 | 1,038.2 | 1,170.2 | .342 | 7.0 | 2.42 | [1].21 |
| Grand average | 8.1 | 7.08 | 14.9 | 107.0 | 4.62 | 197 | 896.8 | 1,003.8 | .334 | 6.5 | 2.19 | [1].22 |

SILAGE RATION

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1934: | | | | | | | | | | | | |
| 1 | 6 | | | | 6.76 | 107 | 723.3 | 723.3 | 0.351 | 6.4 | 2.25 | 0.22 |
| 2 | 6 | | | | 7.94 | 134 | 1,063.9 | 1,063.9 | .421 | 6.4 | 2.69 | .25 |
| 3 | 6 | | | | 10.39 | 199 | 2,067.8 | 2,067.8 | .328 | 5.1 | 1.67 | .08 |
| 4 | 6 | | | | 11.48 | 109 | 1,251.3 | 1,251.3 | .335 | 6.5 | 2.18 | .17 |
| 5 | 6 | | | | 10.57 | 156 | 1,648.9 | 1,648.9 | .244 | 6.0 | 1.46 | .09 |
| Average | 6 | | | | 9.43 | 141 | 1,351.0 | 1,351.0 | .336 | 6.1 | 2.05 | [1].15 |
| 1935: | | | | | | | | | | | | |
| 6 | 7 | | | | 10.88 | 288 | 3,133.4 | 3,133.4 | .317 | 8.3 | 2.63 | .08 |
| 7 | 7 | | | | 10.88 | 268 | 2,915.8 | 2,915.8 | .317 | 8.2 | 2.60 | .09 |
| 8 | 8 | | | | 9.48 | 251 | 2,379.5 | 2,379.5 | .391 | 6.1 | 2.39 | .10 |
| 9 | 9 | | | | 8.98 | 233 | 2,092.3 | 2,092.3 | .391 | 6.7 | 2.49 | .12 |
| 10 | 10 | | | | 7.03 | 157 | 1,103.7 | 1,103.7 | .375 | 7.5 | 2.81 | .26 |
| 11 | 10 | | | | 7.39 | 205 | 1,514.9 | 1,514.9 | .259 | 6.8 | 1.76 | .12 |
| 12 | 10 | | | | 6.53 | 260 | 1,697.8 | 1,697.8 | .229 | 7.2 | 1.65 | .10 |
| Average | 8.7 | | | | 8.74 | 237 | 2,119.6 | 2,119.6 | .326 | 7.3 | 2.33 | [1].11 |
| Grand average | 7.6 | | | | 9.02 | 197 | 1,799.4 | 1,799.4 | .330 | 6.8 | 2.22 | [1].12 |

[1] Percentage based on weighted average.

The relation between average daily carotene consumption and the percentage of the ingested carotene transmitted unchanged to butterfat, based on 36 observations, is shown graphically in figure 2.

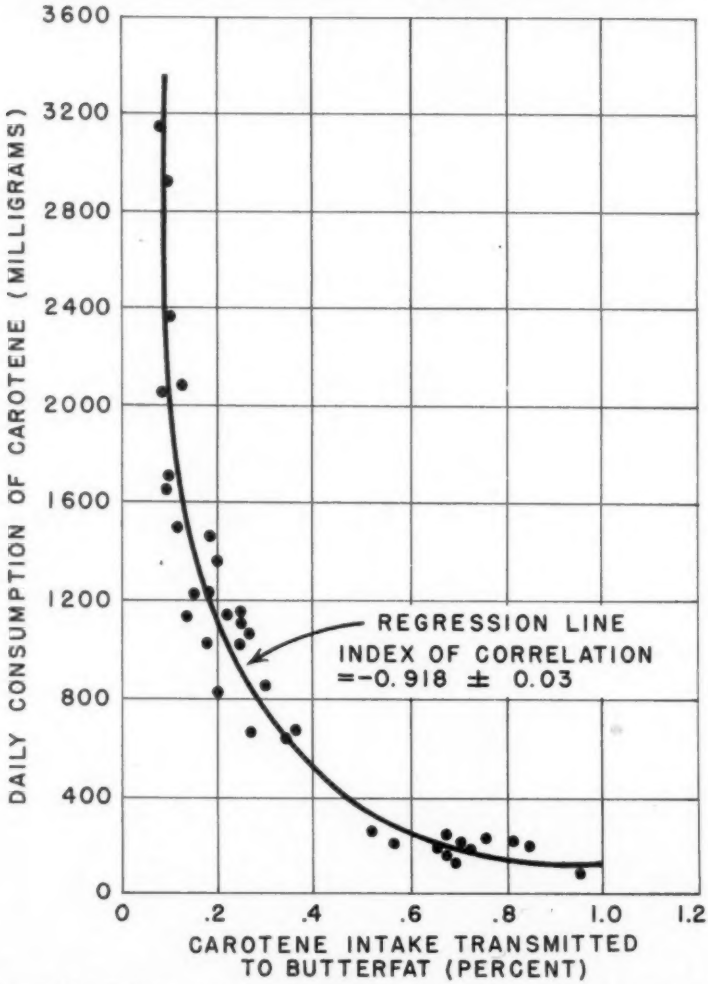


FIGURE 2.—Relation between daily carotene intake and the percentage of the intake transmitted to butterfat in the form of carotene, based on 36 observations.

Table 3 shows the growth made by rats fed different amounts of the different samples of butterfat, also the apparent vitamin A activity of each sample. The vitamin A activity was calculated on the basis of the average growth made by reference groups of rats in experiments 2 and 3 that were fed a known number of vitamin A units in U. S. P.x

reference oil. In each of the three experiments representative groups of animals were maintained on the basal diet as negative controls. In the first experiment seven rats survived an average of 11 days and lost an average of 9 g. In the second experiment 10 rats survived an average of 15 days and lost 17 g. In the third experiment seven rats survived an average of 15 days and lost 19 g.

TABLE 3.—*Vitamin A content of butterfat produced by cows on different roughage rations, as determined on the basis of U. S. P.x (1934) reference cod-liver oil and also by the Sherman unit growth method*

EXPERIMENT 1 (1934)

| Ration fed to cows producing the butterfat | Experimental rats: Lot No. | Experimental rats: Per lot | Amount of butterfat fed daily | Average gain per rat in 5-week period | Factor for gain per unit of vitamin A | Vitamin A fed in butterfat or cod-liver oil | Vitamin A per gram of butterfat by—: U. S. P.x method | Vitamin A per gram of butterfat by—: Sherman method | Decrease by U. S. P.x method: Units | Decrease by U. S. P.x method: Percent |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Number* | *Milligrams* | *Grams* | *Grams* | *Units* | *Units* | *Units* | *Units* | *Percent* |
| Hay | 1 | 10 | 40 | 36.6 | [1] 0.575 | 63.6 | 45.5 | 50.8 | 5.3 | 10.4 |
| | 2 | 9 | 80 | 64.0 | [1] .575 | 111.3 | 39.8 | 44.5 | 4.7 | 10.6 |
| | 3 | 10 | 160 | 83.1 | [1] .575 | 144.5 | 25.8 | 28.9 | 3.1 | 10.7 |
| Silage | 4 | 10 | 40 | 61.0 | [1] .575 | 106.1 | 75.8 | 84.8 | 9.0 | 10.6 |
| | 5 | 9 | 80 | 82.7 | [1] .575 | 143.8 | 51.4 | 57.4 | 6.0 | 10.5 |
| | 6 | 11 | 160 | 101.2 | [1] .575 | 176.0 | 31.4 | 35.1 | 3.7 | 10.5 |
| Hay and silage | 7 | 9 | 40 | 60.3 | [1] .575 | 104.9 | 74.9 | 83.8 | 8.9 | 10.6 |
| | 8 | 10 | 80 | 81.4 | [1] .575 | 141.6 | 50.6 | 56.5 | 5.9 | 10.4 |
| | 9 | 10 | 160 | 89.0 | [1] .575 | 154.8 | 27.6 | 30.9 | 3.3 | 10.7 |

EXPERIMENT 2 (1935)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pasture | 1 | 9 | 10 | 7.1 | [2] 0.595 | 11.9 | 34.0 | 39.4 | 5.4 | 13.7 |
| | 2 | 9 | 20 | 43.8 | [2] .595 | 73.6 | 105.1 | 122.0 | 16.9 | 13.9 |
| | 3 | 10 | 40 | 63.8 | [2] .595 | 107.2 | 76.6 | 88.5 | 11.9 | 13.5 |
| | [3] 4 | 10 | [4] | 30.7 | .600 | 50.5 | | | | |
| | [3] 5 | 10 | [5] | 41.0 | .590 | 70.0 | | | | |

EXPERIMENT 3 (1935)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hay | 1 | 8 | 21.5 | 9.1 | [6] 0.555 | 16.4 | 21.8 | 23.5 | 1.7 | 7.2 |
| | 2 | 8 | 43.0 | 46.5 | [6] .555 | 83.8 | 55.9 | 60.1 | 4.2 | 7.0 |
| Silage | 3 | 8 | 21.5 | 49.2 | [6] .555 | 88.6 | 117.8 | 127.1 | 9.3 | 7.3 |
| | 4 | 8 | 43.0 | 76.8 | [6] .555 | 138.4 | 92.3 | 99.2 | 6.9 | 7.0 |
| Hay and silage | 5 | 7 | 21.5 | 40.4 | [6] .555 | 72.8 | 96.8 | 104.2 | 7.4 | 7.1 |
| | 6 | 8 | 43.0 | 90.8 | [6] .555 | 163.6 | 109.1 | 117.2 | 8.1 | 6.9 |
| | [3] 7 | 7 | [4] | 25.3 | .510 | 50.5 | | | | |
| | [3] 8 | 7 | [5] | 41.7 | .600 | 70.0 | | | | |

[1] Based on the average of the factors for gain per unit of vitamin A by lots 4 and 5 in experiment 2 and lots 7 and 8 in experiment 3.
[2] Based on the average of the factors for gain per unit of vitamin A by lots 4 and 5 in experiment 2.
[3] Received known amounts of vitamin A in the form of U. S. P.x reference cod-liver oil.
[4] Received 1.43 units of vitamin A daily in cod-liver oil.
[5] Received 2.00 units of vitamin A daily in cod-liver oil.
[6] Based on the average of the factors for gain per unit of vitamin A by lots 7 and 8 in experiment 3.

As shown in table 3, the vitamin A values for the experiments were calculated by both the Sherman weight-gain method and the U. S. P.x reference oil method. The vitamin A values for the butterfat were approximately 14 percent lower in experiment 2 and 7 percent lower in experiment 3 when calculated by the U. S. P.x method.

There was a high degree of uniformity in the growth response by the reference groups in experiments 2 and 3. In experiment 2, lots 4 and 5 gained 0.60 and 0.59 g, respectively, in the 5-week period, or an average of 0.595 g per unit of vitamin A fed in cod-liver oil. In experiment 3,

lots 7 and 8 gained 0.51 and 0.60 g, respectively, or an average of 0.555 g per unit of vitamin A fed. The average for all four reference lots was 0.575 g. This factor was used as a basis for calculating the U. S. P.x vitamin A values in experiment 1.

As will be noted by a study of table 3, the different groups of rats did not all produce growth responses in proportion to the amount of butterfat fed. Therefore, the comparative vitamin A activity of the butterfats produced on the different roughage rations has been interpreted by selecting from table 3 the groups of rats that produced a growth response most closely approximating that of the reference groups. Table 4 shows the average vitamin A activity of butterfat produced on hay, on silage, on hay and silage, and on pasture, as indicated by the selected groups of rats.

TABLE 4.—*Average vitamin A activity of butterfat produced on hay, on hay and silage, on silage, and on pasture, as indicated by selected groups of rats*

| Ration fed to cows producing the butterfat | Experiment No. | Lot No. | Rats per lot | Amount of butterfat fed daily | Average gain per rat in 5-week period | Gain per unit of vitamin A by reference groups | Vitamin A per gram of butterfat |
|---|---|---|---|---|---|---|---|
| | | | *Number* | *Milligrams* | *Grams* | *Grams* | *Units* |
| Hay | 1 | 1 | 10 | 40 | 36.6 | 0.575 | 45 |
| | 3 | 2 | 8 | 43 | 46.5 | .555 | 56 |
| Average | | | | | | | 50 |
| Hay and silage | 1 | 7 | 9 | 40 | 60.3 | .575 | 75 |
| | 3 | 6 | 7 | 21.5 | 40.4 | .555 | 97 |
| Average | | | | | | | 86 |
| Silage | 1 | 4 | 9 | 40 | 61.0 | .575 | 76 |
| | 3 | 3 | 8 | 21.5 | 49.2 | .555 | 118 |
| Average | | | | | | | 97 |
| Pasture | 2 | 2 | 9 | 20 | 43.8 | .595 | 105 |

It is apparent that pasture grass produced butterfat more than twice as high in vitamin A activity as did the hay ration; while the silage produced butterfat 1.9 times as high in vitamin A, and the hay and silage 1.7 times as high as the hay.

The total daily production of vitamin A per cow in the butterfat produced on the various rations, as expressed in U. S. P. x (revised 1934) units, was approximately 18,000 for the cows on the hay ration, 28,000 for the cows on the hay and silage ration, and 32,000 for the cows on the all silage ration.

Table 5 has been prepared to show the relationship of the carotene content of butterfat to its total vitamin A activity. For this purpose 0.6 microgram of carotene has been taken as equivalent to one U. S. P. x (revised 1934) unit of vitamin A. While this equivalence has been questioned in the case of butterfat (*2*) its use gives relative figures which show a rather constant ratio of carotene content to vitamin A activity in the butterfat. It appears that regardless of the amount of carotene in the ration these cows maintained a relatively constant ratio of carotene to total vitamin A activity in their butterfat.

TABLE 5.—*Average carotene content of butterfat produced on four different roughage rations, and the percentage of total vitamin activity in the butterfat attributable to the carotene in the butterfat*

| Ration fed to cows producing the butterfat | Experiment No. | Average carotene content of butterfat per gram | Vitamin A attributed to carotene in butterfat | | Total vitamin A activity of butterfat |
|---|---|---|---|---|---|
| | | *Micrograms* | *Units* [1] | *Percent* | *Units* |
| Hay | 1 | 2.83 | 4.7 | 10.35 | 45 |
| | 3 | 4.05 | 6.7 | 11.96 | 56 |
| Average | | 3.44 | 5.7 | 11.16 | 50 |
| Hay and silage | 1 | 5.71 | 9.5 | 12.68 | 75 |
| | 3 | 7.33 | 12.2 | | 97 |
| Average | | 6.52 | 10.8 | 12.68 | 86 |
| Silage | 1 | 5.94 | 9.9 | 13.06 | 76 |
| | 3 | 6.77 | 11.3 | 9.58 | 118 |
| Average | | 6.36 | 10.6 | 11.32 | 97 |
| Pasture | 2 | 8.63 | 14.4 | 13.71 | 105 |

[1] 0.6 microgram of carotene considered equivalent to 1 U. S. P. x (revised 1934) unit of vitamin A.

The vitamin A activity of the butterfats did not follow proportionately the increase in the carotene content of the several rations. The same is true of the vitamin A activity with respect to the color of the butterfat. The ratio of the carotene content of the butterfat and its vitamin A activity remained practically constant for each of the four rations. While a high carotene content of the roughage and a high color content of the butterfat indicated a high vitamin A value, they were much less indicative of the vitamin A value than the carotene content of the butterfat. The carotene content of the feed may indicate in general the carotene content, or vitamin A activity, of the butterfat but it is not an accurate measure.

During the course of this experiment one of the three groups of 10 cows was maintained throughout two winters of 181 and 182 days duration, respectively, on an all-hay ration, with no evidence of vitamin A deficiency on this feeding schedule. Parturition in all cases was normal and the calves were strong, healthy, normal individuals. There is a probability of some carry-over of vitamin A from the pasture season, however. The minimum requirements of carotene for cattle, observed by Guilbert (*8*), are well below the amounts received by the cows on the hay ration.

The real advantage, therefore, in providing high-carotene feeds, above a minimum requirement which is not yet accurately known, is that it improves the vitamin A value of the butterfat in the milk. These studies demonstrate the comparative vitamin A value of the butterfat produced on the various kinds of roughage. The roughage part of a good dairy ration including both hay and silage in the winter and pasture in the summer as fed in this experiment will effectively provide sufficient of the vitamin A factor for maintenance, reproduction, and the production of butterfat of high vitamin A activity.

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## SUMMARY AND CONCLUSIONS

Twelve samples of the home-grown field-cured hay fed in this experiment were analyzed for their green color and their carotene content. In general, the samples containing the highest percentages of green color also were highest in carotene content. This relationship did not hold true for each of the 12 samples, however.

The average carotene content of the hay ration, the hay and silage ration, the grass-silage ration, and the pasture ration was 14.8 micrograms per gram, 57.0 micrograms per gram, 197.3 micrograms per gram, and 260 micrograms per gram, respectively. When these rations were fed as the sole roughage to Holstein-Friesian cows, they produced butterfat with an average carotene content of 3.6 micrograms per gram for hay; 6.5 micrograms per gram for hay and silage; 6.8 micrograms per gram for silage; and 7.9 micrograms per gram for pasture. The increase in the carotene content of the butterfat was not in the same proportion as the increase in the carotene content of the feeds.

There was a good relationship between the color and carotene content of butterfat. For 42 observations the correlation coefficient was $0.866 \pm 0.034$.

The home-grown field-cured hay fed in the winter, which had an average carotene content of 14.8 micrograms per gram in addition to whatever carry-over there might have been from pasture the preceding summer, apparently furnished enough of the vitamin A factor for normal body activities, reproduction, and the production of butterfat of approximately 50 units per gram. The average daily carotene intake was 185 mg.

A ration of home-grown hay and grass silage with an average carotene content of 57 micrograms per gram produced a butterfat with a vitamin A value of approximately 86 units per gram. The average daily carotene intake was 897 mg.

A ration of grass silage with an average carotene content of 197 micrograms per gram produced a butterfat with a vitamin A value of approximately 97 units per gram. The average daily carotene intake was 1,799 mg.

Pasture with an average carotene content of 260 micrograms per gram produced a butterfat of approximately 105 units per gram.

The average percentage of the carotene ingested that was secreted as carotene in the butterfat was 0.71 percent for the cows receiving hay, 0.22 percent for the cows receiving hay and silage, and 0.12 percent for the cows receiving silage.

The carotene in butterfat accounted for only a small percentage of the total vitamin A activity. By assuming that 0.6 microgram of carotene is equivalent to one U. S. P. x (1934 revision) unit of vitamin A the percentage of the vitamin A attributable to carotene in the hay ration was 11.2 percent; hay and silage ration 12.7 percent; silage ration 11.3 percent; and pasture 13.7 percent.

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# THE EFFECT OF ENVIRONMENTAL TEMPERATURE ON MORTALITY, RATE OF GROWTH, AND UTILIZATION OF FOOD ENERGY IN WHITE LEGHORN CHICKS[1]

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## INTRODUCTION

The effect of environmental temperature on growth rate, food consumption, and the conversion of food to body substance in chicks has been investigated by Kleiber and Dougherty (*11*) [3] who studied the effects of air temperatures of 21°, 27°, 32°, 38°, and 40° C. on chicks during the period from 6 to 15 days of age. The daily rate of growth was found to increase as the environmental temperature decreased. Maximum gain in weight was 4.88 g per day at 21°, while minimum gain was 2.74 g per day at 40°. Availability of food, defined as $\frac{\text{food}-\text{excreta}}{\text{food}}$, was optimum at 38°.

Energy stored as gain in body substance (net energy in production) reached a maximum at 32° C. The energy content per unit of weight gained was at a minimum at 21° (1.41 Cal.[4] per gram) and at a maximum (2.95 Cal. per gram) at 38°. Total efficiency (the total net energy produced per unit of food energy consumed) exhibited a maximum of 34 percent at 32° and a minimum at 21°, at which temperature it was 16 percent.

Barott and his coworkers (*2*) studied the effects of environmental temperature on chicks younger than those used by Kleiber and Dougherty. Heat production and gaseous exchange of chicks from 10 to 100 hours of age, at temperatures from 68° to 104° F., were determined with a respiration calorimeter. A "critical temperature" was found at 96°, and a 15-percent increase in metabolism resulted from an increase or decrease of 7° from this temperature. Metabolism increased as environmental temperature decreased from 96° to 70°. The energy output at 70° was twice that at 96°. Deutectomized as well as normal chicks were studied.

Lewis (*13*), using groups of 50 White Leghorn chicks, found that at an average temperature of 29° C. (32° on the first day decreased gradually to 23° on the twenty-eighth day) there was a mortality of 24 percent, while there was a mortality of 10 percent at an average temperature of 34°. Lewis *(13, p. 102)* stated: "This increased death rate was due in nearly every instance to crowding at night in an effort to keep warm."

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[2] The authors are indebted to the members of the staff of the Division of Poultry Husbandry of the College of Agriculture, University of California, for cooperation in supplying suitable eggs for hatching and for the use of miscellaneous items of equipment. The samples of food and excreta were analyzed for nitrogen, carbon, and energy content by A. J. Soderberg.

[3] Italic numbers in parentheses refer to Literature Cited, p. 544.

[4] Cal. as used in this paper = kilogram-calorie.

The work of Kleiber and Dougherty (*11*) at temperatures ranging from 21° to 40° C. gave rise to questions as to the possibility of chicks surviving at temperatures below 21° and as to the relationship between heat production and energy intake at such low temperatures. The present series of trials was carried out to obtain information on these points. It was planned first to conduct trials at temperatures within the range studied by Kleiber and Dougherty for comparison and then to carry out trials at temperatures below this range to determine the lowest environmental temperature at which chicks would be able to grow. In particular, an attempt was made to determine whether there exists a temperature at which growth becomes negligible because all available energy that a chick can take in is used to produce heat for the maintenance of body temperature. In accordance with this plan, chicks were raised in environments the temperatures of which were within the range 21° to 38° C. and at 16° and 18°.

## METHODS

The methods employed were similar to those described by Kleiber and Dougherty (*11*). Ten control birds were used, and five individuals were chosen for each experimental group. The chicks were hatched from trap-nested eggs from a flock in which the males were full brothers. Each individual in the experimental group was represented by two individuals from the same hen in the control group, except in the trial at 35° C., where this was true except in the case of one experimental bird, and in the trial at 18° where each experimental bird was matched with a half brother or sister and with one other individual. Control birds with body weights matching as closely as possible those of the corresponding experimental individuals were chosen.

At temperatures of 21° C. and above, the duration of each trial was 10½ days at full feed, followed by a 36-hour period during which the chicks had free access to water but received no food. The period of fast included the last 12 hours (night) of the twelfth day of each trial during which period fasting katabolism was determined. During the determination of the fasting katabolism little or no activity was observed. The duration of the trials at 16° and 18° was shortened by the failure of some individuals to survive at these temperatures. No fasting katabolism determinations could be made at 16° and 18° because the chicks which lived longer than 10 days were too weak to survive the long period of fasting.

The chicks were allowed free access to food, which was considered adequate for every requirement. The food, prepared in pellet form, contained:

25 parts of ground whole wheat.
25 parts of ground whole yellow corn.
25 parts of ground whole barley.
15 parts of fish scrap with 65 percent protein.
5 parts of dry skim milk.
5 parts of ground bone.

To 100 parts of this mixture were added:

2 parts of pulverized limestone (96 percent $CaCO_3$).
½ part of salt (NaCl).
1 part of cod-liver oil.
1 part of yeast.

Except for the yeast the ration used was identical with that used by Kleiber and Dougherty.

Lemon juice was added to the drinking water in line with the recommendation of Holst and Halbrook (*7*). The discovery of the fat-soluble antihemorrhagic vitamin (Almquist (*1*)) indicates that vitamin C probably was not necessary to the diet. Food intake was governed by the birds' appetite. Appetite in relation to environmental temperature, energy utilization, and rates of growth was thus studied. Kleiber and Dougherty *(11, p. 704)* have discussed appetite as "an important variable which determines in a great many cases the actual level of energy transformation in animals."

The experimental chicks were kept in the climatic cabinet described by Kleiber and Dougherty (*11*). The temperature was maintained automatically and seldom varied by as much as 2° C. from the desired level. Relative humidity was automatically maintained at 50 percent.

Air samples taken at the beginning and end of each (10- to 13-hour) period were analyzed in a modified Haldane apparatus (Kleiber (*9*)).

## RESULTS

### MORTALITY OF CHICKS

The limited number of chicks does not allow definite quantitative conclusions with respect to mortality at the various temperatures, yet the results indicate that the lowest limit of environmental temperature for these chicks was approached in the experiments.

None of the control chicks and none of the experimental birds kept at 21° C. or above died during these trials. At 18° one chick out of five died on the fifth day and one on the tenth day of the trial. The surviving chicks were removed from the chamber on the morning of the eleventh day of the trial. Of five chicks kept at 16°, one died on the sixth, one on the ninth, and one on the tenth day of the trial. The surviving chicks were removed from the chamber on the tenth day.

The chicks that were lost at 16° and 18° C. exhibited (before death) a dropsical condition of the foot and shank accompanied by redness of the skin of the leg and foot. During the last 2 days of life the droppings were sticky. True diarrhea such as that reported by Hall (*6*), who produced diarrhea in chicks by chilling them under a fan for short periods, was not observed. About 24 hours before death the chicks became very weak and failed to eat. On post-mortem examination it was found that the alimentary tract was entirely filled with food in each case. No abnormalties of the internal organs were observed.

The death rate probably was not influenced positively by the tendency of chicks to crowd together at low environmental temperatures, for only five birds were placed in the cabinet at a time. Under the conditions of the experiment huddling together actually may have resulted in a decrease of the death rate since it is a means of saving energy, as Kleiber and Winchester (*12*) have shown.

### EFFECT OF TEMPERATURE ON THE GROWTH RATE OF CHICKS

Chicks hatched late in the season were noticeably smaller than those hatched earlier. To avoid any influence on the results that might have been exerted by seasonal variations in the birds, the mean daily increase in weight of the experimental chicks was calculated as percentage of the mean daily increase of the corresponding controls. The result of this calculation expressed as a curve is given in figure 1.

This curve shows relative rates of growth through a period of 8 days. The rate of increase in weight per day was $2.2 \pm 0.4$ g [5] for the chicks kept at 16° C., while the mean rate of increase for the experimental chicks kept at temperatures higher than 16° (18° to 38°, inclusive) was $3.9 \pm 0.3$ g per day. That of all the control birds was $4.4 \pm 0.3$ g per day. Growth rate data are given in table 1.

Growth rate was slowest at 16°, and most rapid at 21° C. as is shown by the next to the last column in table 1. Kleiber and Dougherty (*11*) observed that the rate of growth increased as environmental

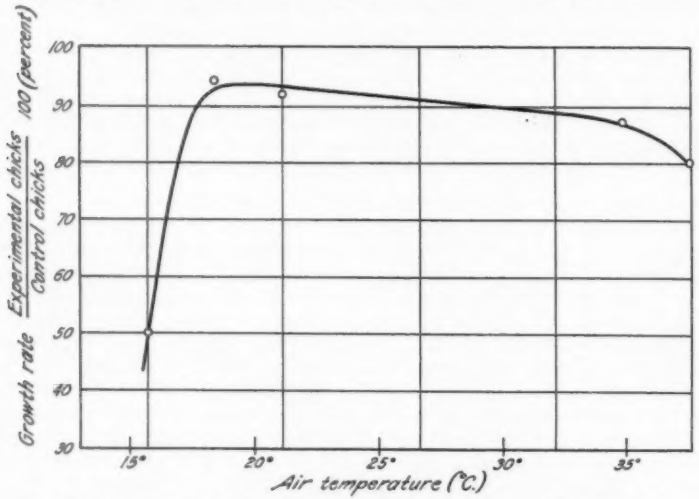


FIGURE 1.—Mean daily increase in weight of chicks kept at different temperatures, expressed as percentage of mean daily increase of corresponding controls. Rates of growth shown during a period of 8 days.

temperature was decreased to 21°, which parallels the results of the present experiment in a corresponding temperature range. That growth took place at all at 16° is a rather remarkable fact. The manner in which energy was spared for growth at this (comparatively) low temperature will be discussed later.

TABLE 1.—*Weight and growth-rate data for chicks kept at different temperatures*

| Environmental temperature (°C.) | Experimental groups | | | | |
|---|---|---|---|---|---|
| | Mean weight of chicks at start of trial | Mean weight of chicks at end of 8 days | Mean weight of chicks at end of 11 days | Mean daily increase through period of 8 days | Mean daily increase through period of 11 days |
| | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* |
| 38 | 35.5±0.9 | 58.0±1.3 | 69.4±1.6 | 2.8±0.2 | 3.1±0.2 |
| 35 | 50.1± .8 | 86.1±2.5 | 102.5±3.4 | 4.5± .3 | 4.8± .4 |
| 21 | 45.0±1.3 | 77.2±2.3 | 99.2±3.3 | 4.0± .3 | 4.9± .3 |
| 18 | 47.9±1.4 | 83.2±2.3 | ---------- | 4.4± .3 | ---------- |
| 16 | 43.8±1.0 | 61.1±2.8 | ---------- | 2.2± .4 | ---------- |

[5] Throughout this paper the figure following the sign refers to the standard error of the mean.

TABLE 1.—*Weight and growth-rate data for chicks kept at different temperatures*—Continued

| Environmental temperature (°C.) | Control groups | | | | | Daily increase of experimental chicks expressed as percentage of daily increase of control chicks at ages shown | |
|---|---|---|---|---|---|---|---|
| | Mean weight of chicks at start of trial | Mean weight of chicks at end of 8 days | Mean weight of chicks at end of 11 days | Mean daily increase through period of 8 days | Mean daily increase through period of 11 days | 8-day period | 11-day period |
| | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* | *Percent* | *Percent* |
| 38 | 34.9±1.5 | 63.0±1.4 | 78.5±1.9 | 3.5±0.3 | 4.0±0.2 | 80.0 | 77.5 |
| 35 | 50.2±1.1 | 91.2±2.4 | 109.0± .7 | 5.1± .3 | 5.3± .5 | 88.2 | 90.6 |
| 21 | 44.9± .9 | 79.7±2.0 | 102.8±1.9 | 4.3± .3 | 5.3± .2 | 93.0 | 92.4 |
| 18 | 47.7± .9 | 86.3±2.3 | | 4.8± .3 | | 91.7 | |
| 16 | 43.8±1.0 | 78.3±1.7 | | 4.3± .2 | | 51.2 | |

A formula for determining the relative rate of growth during the accelerating phase of growth has been given by Brody (*4*). The formula is as follows:

$$\frac{dW}{dt}=kW$$

where

$W$=*body weight in grams*
$t$=time in days

The integrated form has been used for these calculations, namely:

$$k=\frac{lnW_2-lnW_1}{t_2-t_1}=2.30259\,\frac{\log W_2-\log W_1}{t_2-t_1}$$

The calculations were based on the weights obtained the morning of the fifth day of life and those obtained on the morning of the ninth, the thirteenth, and the sixteenth day. The results of these calculations are given in table 2. The relative rate of growth at 16° C. was distinctly lower than that at any higher temperature.

The growth rates of chicks raised at 16° and 18° C. are given for the first 8 days of the trial only, since some chicks kept at the two lower temperatures did not survive longer.

TABLE 2.—*Relative growth rate of chicks of various ages, kept at different temperatures as determined by Brody's formula;*

$$k=2.30259\frac{(\log W_2-\log W_1)}{(t_2-t_1)}$$

| Air temperature (°C.) | Percent growth per day: (100 k) during period of age indicated | | | | |
|---|---|---|---|---|---|
| | 5-8 days (inclusive) | 9-12 days (inclusive) | 13-15 days (inclusive) | 5-12 days (inclusive) | 5-15 days (inclusive) |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| 16 | 2.6 | 5.8 | | 4.2 | |
| 18 | 6.1 | 7.7 | | 6.9 | |
| 21 | 5.9 | 7.6 | 8.4 | 6.8 | 7.2 |
| 35 | 7.5 | 6.1 | 5.8 | 6.8 | 6.5 |
| 38 | 5.5 | 6.7 | 6.0 | 6.1 | 6.1 |

EFFECT OF TEMPERATURE ON FOOD CONSUMPTION, RATE OF EXCRETION, AND AVAILABILITY OF NUTRIENTS

During the period from the fifth to the twelfth days, inclusive, (during which it was possible to make comparisons of chicks at all the temperatures used) the food consumption per chick was greatest at 18° C. and least at 38°. Because of the variations in weight of the birds, a better comparison can be made in terms of body size. Kleiber (*8*) has found the 0.75 power of the body weight to be the most suitable means of comparing the metabolism of animals of various sizes. Brody and Procter (*5*) found the 0.73 power of the body weight to be best for making comparisons of metabolism. The 0.75 power of the body weight is used throughout this paper for comparing the body weight of chicks. The symbol $kg^{3/4}$ is used here as the unit of the 0.75 power of the body weight expressed in kilograms.

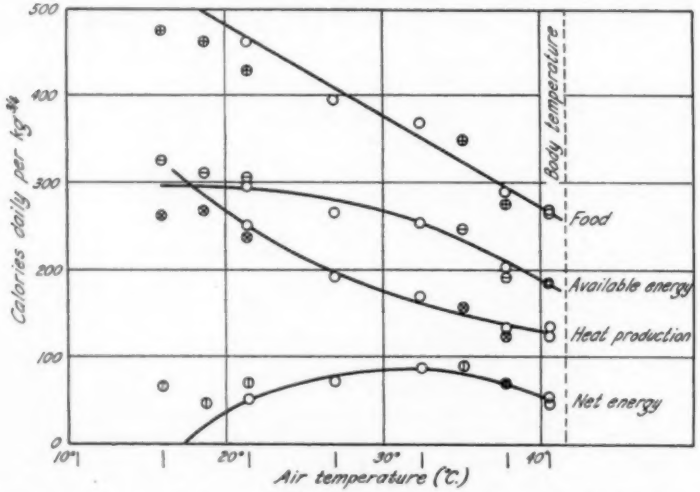


FIGURE 2.—Rate of food consumption and heat production by, and net and available energy of food of chicks as related to environmental temperature. Curves are those of Kleiber and Dougherty (*11, p. 717*). The original points are represented by circles; corresponding data from the present experiment are indicated by circles enclosing crosses, and horizontal and vertical lines.

The chicks kept in an environment of 16° C. consumed more food per $kg^{3/4}$ than those kept at higher temperatures. The relation of food consumption and environmental temperature seems to be nearly linear, as figure 2 shows.

Availability of food was somewhat greater at 21°, 35°, and 38° C. than at 16° and 18° (table 3). The term "availability" as employed here means the amount of dry matter retained by the body, expressed as percentage of the dry matter consumed. The dry matter not excreted is "available" either for production of body substance or for production of heat. This conception is very useful in nutrition work with chicks where *digestibility* of food would be difficult to determine owing to the fact that feces and urine of birds cannot easily be sep-

arated. The results for the various periods of each trial agree quite closely.

The availability for the period including the fifth and twelfth days is plotted against the environmental temperatures in figure 3. At 35° and 38° C. the availability was very similar to that determined by Kleiber and Dougherty, who found the maximum at 38°; but in the present

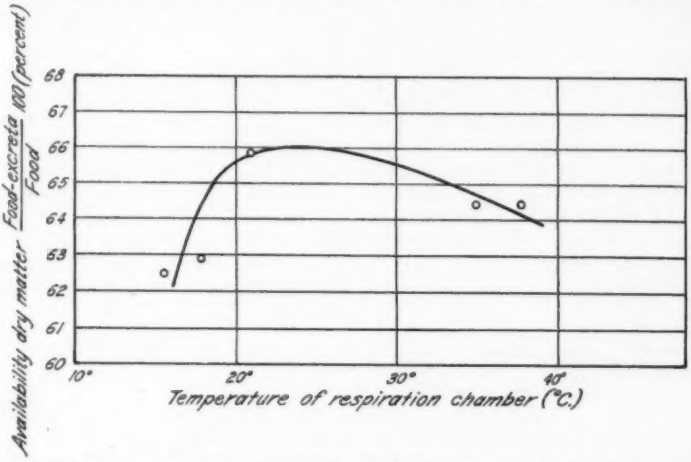


FIGURE 3.—Availability of food dry matter to chicks as influenced by environmental temperature.

experiment maximum availability of nearly 66 percent was found at 21°, while availability at 16° and at 18° was approximately 63 percent as compared with more than 64 percent at 35° and 38°, during the fifth to twelfth day period.

TABLE 3.—*Food consumption, excretion, and food availability per day for chicks of various ages kept at different temperatures, expressed on a dry-matter basis*

| Age (days) | Item | Data for indicated air temperature | | | | |
|---|---|---|---|---|---|---|
| | | 16° C. | 18° C. | 21° C. | 35° C. | 38° C. |
| 5-8 | Food ..... grams | 9.67 | 10.78 | 9.73 | 10.11 | 5.64 |
| | Excretion ..... do | 3.65 | 4.10 | 3.47 | 3.51 | 2.05 |
| | Available ..... do | 6.02 | 6.68 | 6.26 | 6.60 | 3.59 |
| | Availability ..... percent | 62.30 | 62.00 | 64.30 | 65.30 | 63.70 |
| 9-12 | Food ..... grams | 14.79 | 16.74 | 15.10 | 11.86 | 7.56 |
| | Excretion ..... do | 5.49 | 6.10 | 5.00 | 4.30 | 2.65 |
| | Available ..... do | 9.30 | 10.64 | 10.10 | 7.56 | 4.91 |
| | Availability ..... percent | 62.90 | 63.60 | 66.90 | 63.70 | 65.00 |
| 13-15 | Food ..... grams | ..... | ..... | 20.15 | 12.67 | 9.27 |
| | Excretion ..... do | ..... | ..... | 6.67 | 4.24 | 3.46 |
| | Available ..... do | ..... | ..... | 13.48 | 8.43 | 5.81 |
| | Availability ..... percent | ..... | ..... | 66.90 | 66.50 | 62.70 |
| 5-12 | Food ..... grams | 12.23 | 13.76 | 12.42 | 10.99 | 6.60 |
| | Excretion ..... do | 4.57 | 5.10 | 4.24 | 3.91 | 2.35 |
| | Available ..... do | 7.66 | 8.66 | 8.18 | 7.08 | 4.25 |
| | Availability ..... percent | 62.60 | 62.90 | 65.90 | 64.40 | 64.40 |
| 5-15 | Food ..... grams | ..... | ..... | 14.53 | 11.45 | 7.33 |
| | Excretion ..... do | ..... | ..... | 4.99 | 4.00 | 2.65 |
| | Available ..... do | ..... | ..... | 9.54 | 7.45 | 4.68 |
| | Availability ..... percent | ..... | ..... | 65.70 | 65.10 | 63.90 |

Considering the fact that the digestive systems of the birds at the two lower temperatures were probably taxed to full capacity, an availability of 63 percent at 16° and 18° C. seems quite favorable as compared with availabilities of 64 to 66 percent observed at more nearly optimal temperatures. The ration used was as nearly as possible equal to that fed by Kleiber and Dougherty except for the addition of yeast to the feed and lemon juice to the drinking water. The greatest difference between the availability observed in this trial and that of the authors mentioned was 8 percent at 21°.

### RESPIRATORY EXCHANGE OF CHICKS AS AFFECTED BY TEMPERATURE

The metabolism of chicks apparently tended to increase as environmental temperature was lowered to 18° C. This result parallels the observations of Kleiber and Dougherty. The carbon dioxide production per $kg^{3/4}$ is larger in the present series of trials than in the earlier series at each environmental temperature. Maximum $CO_2$ per $kg^{3/4}$ was produced at 18° during the first 8 days of the trial (table 4). At each level of temperature above 18° C. the carbon dioxide production was successively lower. At 16° the $CO_2$ production was less than that at 18°.

TABLE 4.—*Carbon dioxide produced per day by chicks of various ages kept at different temperatures*

| Basis, period, and age of chicks | Data for indicated environmental temperatures | | | | |
|---|---|---|---|---|---|
| | 16° C. | 18° C. | 21° C. | 35° C. | 38° C. |
| Per chick | *Liters* | *Liters* | *Liters* | *Liters* | *Liters* |
| Period 1 (5–8 days) | 4.87 | 5.55 | 4.61 | 3.95 | 2.20 |
| Period 2 (9–12 days) | 6.31 | 7.32 | 6.67 | 4.62 | 2.81 |
| Period 3 (13–15 days) | | | 8.42 | 6.09 | 3.49 |
| 5–12 days | 5.59 | 6.44 | 5.64 | 4.29 | 2.54 |
| 5–15 days | | | 6.40 | 4.78 | 2.75 |
| Per kilogram of body weight [1] | | | | | |
| Period 1 (5–8 days) | 105.1 | 108.2 | 93.3 | 71.0 | 54.7 |
| Period 2 (9–12 days) | 93.2 | 106.6 | 103.9 | 62.4 | 57.6 |
| Period 3 (13–15 days) | | | 99.6 | 65.8 | 58.1 |
| 5–12 days | 97.9 | 107.3 | 99.3 | 66.2 | 56.3 |
| 5–15 days | | | 99.4 | 66.0 | 56.9 |
| Per $kg^{3/4}$ | | | | | |
| Period 1 (5–8 days) | 48.7 | 51.4 | 43.9 | 34.3 | 24.3 |
| Period 2 (9–12 days) | 47.1 | 54.2 | 52.5 | 32.5 | 26.8 |
| Period 3 (13–15 days) | | | 53.3 | 36.2 | 28.8 |
| 5–12 days | 47.8 | 52.8 | 48.2 | 33.5 | 25.9 |
| 5–15 days | | | 50.4 | 33.7 | 26.7 |

[1] Average of mean daily body weights.

TABLE 5.—*Respiratory quotients of full-fed chicks of various ages kept at different temperatures*

| Age of chicks (days) | Respiratory quotients for indicated environmental temperature | | | | | |
|---|---|---|---|---|---|---|
| | 16° C. | | 18° C. | | 35° C. | |
| | Day | Night | Day | Night | Day | Night |
| 5–8 | 1.005 | 0.830 | 0.961 | 0.843 | 0.996 | 0.990 |
| 9–12 | 1.001 | .812 | .931 | .820 | 1.029 | .972 |
| 5–12 | 1.003 | .820 | .950 | .831 | 1.012 | .981 |
| Day and night | 0.912 | | 0.889 | | 0.998 | |

The respiratory exchange at 18° C. during the first 8 days was slightly more than twice that at 38°. Respiratory quotients of full-fed chicks are given in table 5 for the trials at 16°, 18°, and 35°.[6] Kleiber and Dougherty (*11*, pp. 714–715) have stated that "there seems to be a tendency for the R. Q. to be lower at the extremely low and high air temperatures." This tendency appears to have been confirmed for low temperatures in the present experiment, as the respiratory quotients at 16° and 18° were 0.912 and 0.889, respectively, while the lowest respiratory quotient reported in the experiment just cited was 0.971 (at 21°). At 35° the respiratory quotient (in the present trials) was 0.998, which is quite close to an average of the respiratory quotients reported earlier (*11*) for 32° and 38°. Marked variations between day and night respiratory quotients similar to those reported earlier were observed. Kleiber and Dougherty assume that the lower respiratory quotient found at night was a result of decreased fat production of the birds during the hours that they were without food. A comparison of the respiratory quotients in table 5 with those in table 7 shows the respiratory quotients at full feed to be much higher than those of fasting chicks.

### NITROGEN, CARBON, AND ENERGY BALANCE

The excreta and food were analyzed for nitrogen, carbon, and energy content. The quantities of dry matter ingested and excreted daily were determined. The differences between the amounts of nitrogen, carbon, and energy ingested and those excreted are the quantities available for production of body substance or for combustion. For each liter of carbon dioxide given off by the animal 0.5359 g of carbon was subtracted from the total carbon available. The balance is considered as the net carbon or the carbon stored in the body. To find the amount of protein gained, the figure for available nitrogen was multiplied by 6.25 and to find the amount of carbon in the protein gained, the amount of available nitrogen was multiplied by 3.25. The amount of carbon in the body fat produced during the trial was found by subtracting the amount of carbon in the protein from the total amount of carbon stored. The net energy [7] gained was found by obtaining the sum of the heat of combustion of stored fat and of protein gained.[8] The difference between the available energy intake and net energy gained was considered equivalent to the heat production of the animal.

Data on energy metabolism are given in table 6. Since some of the chicks held at 16° and 18° C. died during the first few days of the trials, the results for these trials are given only for the period from 5 to 12 days inclusive, and, for purposes of comparison, data for the first 8 days of the other trials are given, as well as the data obtained during the 11-day period when chicks at temperatures of 21° and above were at full feed.

The hypothesis of Kleiber and Dougherty that "with lower temperature, the heat production tends to approach the energy intake, since the latter is naturally limited," seems to be confirmed by the results

[6] At temperatures of 21° and 38° C. oxygen consumption was measured only during the fasting katabolism determinations.

[7] As used here the term "net energy" or "net energy in production" refers to energy in body substance gained.

[8] 1 g of protein = 5.7 Cal. (kilogram-calories).
1 g of fat = 9.5 Cal. (kilogram-calories).

of the present trials. During the first 8 days of the trial at 38° C., 44 percent of the energy taken in was used to produce heat; at 35°, 45 percent; at 21°, 55 percent; and at 18°, 58 percent. The heat production per $kg^{.75}$ was greater with each decrease in environmental temperature, including the trial conducted at 18°. At 16°, however, the heat production was 261.7 Cal. as compared with 266.1 Cal. per $kg^{.75}$ at 18°. It is difficult to account for a lower rate of heat production at 16° than at 18° unless it be assumed that the mean body temperature was lower at 16° than at 18°. This assumption would also help to explain the surprising fact that net energy in production was found to be greater at 16° than at 18°. At 16° net energy in production was 63.5 Cal. per $kg^{.75}$, while at 18° it was 45.7 Cal. per $kg^{.75}$. During the first 8 days of the trials the mean net energy in production was 75.7 Cal. per $kg.^{.75}$ at 21°, 35°, and 38°; and for the entire 11-day period the corresponding figure was 74.2. The only record that the writers have found of reduced body temperature in birds at low environmental temperature is that of Benedict and his coworkers (*3*), who found that the mean rectal temperatures of a group of mature homozygous frizzle fowl, determined during a period of 3 days at environmental temperatures ranging from 5.6° to 13.9°, was 41.2° as compared with 41.6° for a group of normal chickens under the same conditions.

TABLE 6.—*Energy transformation at full feed, and composition and energy content of the daily gain of body weight, for chicks kept at different environmental temperatures while 5 to 12 and 5 to 15 days old*

| Item | Data for indicated environmental temperature and age of chicks | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 16° C., 5 to 12 days | 18° C., 5 to 12 days | 21° C. | | 35° C. | | 38° C. | |
| | | | 5 to 12 days | 5 to 15 days | 5 to 12 days | 5 to 15 days | 5 to 12 days | 5 to 15 days |
| Mean body weight.....grams.. | 52.4 | 65.5 | 61.1 | 72.1 | 68.1 | 76.3 | 46.7 | 52.4 |
| Mean body size, $kg^{.75}$..... | .110 | .130 | .123 | .140 | .133 | .145 | .102 | .110 |
| Energy in food per day per $kg^{.75}$, Calories.. | 472.7 | 461.3 | 429.4 | 441.3 | 351.3 | 335.8 | 275.1 | 283.3 |
| Energy in excreta per day per $kg^{.75}$, Calories.. | 147.5 | 149.5 | 122.3 | 126.5 | 104.2 | 97.9 | 84.2 | 88.2 |
| Available energy per day per $kg^{.75}$, Calories.. | 325.2 | 311.8 | 307.1 | 314.8 | 247.1 | 237.9 | 190.9 | 195.1 |
| Heat production per day per $kg^{.75}$, Calories.. | 261.7 | 266.1 | 237.9 | 235.4 | 158.8 | 168.3 | 121.3 | 121.4 |
| Energy in gained body substance per day per $kg^{.75}$.....Calories.. | 63.5 | 45.7 | 69.2 | 79.4 | 88.3 | 69.6 | 69.6 | 73.7 |
| Daily gain in body weight....grams.. | 2.16 | 4.41 | 4.03 | 4.93 | 4.51 | 4.76 | 2.81 | 3.08 |
| Daily production of body protein grams.. | .81 | 1.06 | 1.06 | 1.25 | 1.06 | 1.19 | .63 | .69 |
| Daily production of body fat....do.... | .25 | −.01 | .26 | .42 | .60 | .35 | .37 | .44 |
| Energy in body substance gained daily.....Calories.. | 6.99 | 5.94 | 8.51 | 11.12 | 11.74 | 10.10 | 7.10 | 8.11 |
| Body protein per gram increase in body weight.....grams.. | .375 | .240 | .263 | .254 | .235 | .250 | .224 | .224 |
| Body fat per gram increase in body weight.....grams.. | .116 | −.003 | .065 | .085 | .133 | .074 | .132 | .143 |
| Inorganic matter per gram increase in body weight (mostly water) grams.. | .509 | .762 | .672 | .661 | .632 | .676 | .644 | .633 |
| Energy per gram increase in body weight.....Calories.. | 3.24 | 1.35 | 2.11 | 2.26 | 2.60 | 2.12 | 2.53 | 2.63 |

Figure 2 represents the relationship between the temperature of the air and the energy transformations in the birds' bodies. The energy exchange is calculated per $kg^{3/4}$ in order to avoid any possible influence of body size. The curves given in figure 2 are reproduced from the work of Kleiber and Dougherty (*11*), and because the data obtained in the present experiment confirm the earlier work insofar as the higher temperatures are concerned, new curves have not been fitted. At 16° and 18° C. the extrapolations of Kleiber and Dougherty do not seem to fit the data obtained in the present experiment, which can be explained by the fact that the extrapolations were based on the assumption that body temperature and specific insulation of the chicks would remain constant. As has been mentioned, it is assumed that the mean body temperature of the chicks was reduced at a low environmental temperature, for otherwise these results could not easily be explained.

### COMPOSITION AND ENERGY CONTENT OF SUBSTANCE GAINED BY BODIES OF CHICKS

The effects of environmental temperatures on the daily production of protein, fat, and net energy are shown in table 6. Carbon and nitrogen balances were used in calculating the energy metabolism of the chicks on the assumption that the organic constituents of the body substance gained were mainly protein and fat. For the 8-day period there was no production of body fat at 18° C. Fat storage at 16° was approximately equal to that of 21°, but less than that at 35° and 38° during the first 8 days of the trial.

The daily gain of protein per chick was 1.06 g during the first 8 days of the trial at 18°, 21°, and 35° C. At 16° where the daily gain of body weight was markedly lower, daily gain of protein was 0.81 g. At 38°, where the daily gain in weight was also comparatively low, the gain in protein was 0.63 g. Except at 16° the gain in protein per gram increase in body weight ranged only from 0.22 g at 38° to 0.26 g at 21°. Kleiber and Dougherty (*11*) found that the gain in protein changed only from 0.22 to 0.27 g per gram of increase in body weight at temperatures ranging from 21° to 40°. At 16° in the present series of trials 0.37 g of protein was gained per gram of body substance gained.

At 16° C. 7 Cal. of net energy was gained daily, while at 18°, where the daily gain in body weight was more than twice that at 16°, the daily gain in net energy was approximately 6 Cal. This seems to confirm the statement that "the body weight is no general criterion for the effect of food on energy storage in the animal." At 18° water and other inorganic materials constituted 76.2 percent of the gain in body weight, while at 21° the content of inorganic material was 67.2 percent during the same period of the trial (fifth to twelfth days inclusive). At 16° the water content of body substance gained was 50.9 percent. This was far lower than the water content of body substance gained at any higher temperature.

### FASTING KATABOLISM

Rates of fasting katabolism were determined over a period of approximately 12 hours during the night. The chicks were fasted 24 hours before the beginning of these determinations. Since the chicks

kept at 16° and 18° C. were too weak to survive a 36-hour fast, no determinations of fasting katabolism could be made of these two groups. Rates of fasting katabolism of the birds kept at 21°, 35°, and 38° are given in table 7. These results are calculated to a 24-hour basis. A standard of 4.7 Cal. per liter of oxygen consumed was used to determine the heat production of the chicks.

TABLE 7.—*Fasting katabolism (calculated to 24-hour basis) of chicks at 16 days of age, when kept at different temperatures*

| Air temperature (°C.) | Body weight | $kg^{3/4}$ | Daily respiratory exchange per chick calculated to 24 hours | | Respiratory quotient | Daily heat production | | |
|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $O_2$ | | Per chick | Per kilogram | Per $kg^{3/4}$ |
| | *Grams* | | *Liters* | *Liters* | | *Calories* | *Calories* | *Calories* |
| 21 | 84.2 | 0.156 | 3.70 | 5.24 | 0.706 | 24.6 | 292 | 158 |
| 35 | 95.7 | .172 | 2.58 | 3.59 | .719 | 16.9 | 177 | 98 |
| 38 | 62.5 | .125 | 1.69 | 2.32 | .728 | 10.9 | 174 | 87 |

Daily heat production as determined in this series of trials was somewhat greater than that reported by Kleiber and Dougherty (*11*). At 21° C. the daily heat production per $kg^{\frac{3}{4}}$ was 158 Cal., whereas Kleiber and Dougherty found daily heat production to be 128 Cal. at this temperature. Similarly, daily heat production at 35° and 38° was 98 and 87 Cal. respectively. Kleiber and Dougherty found daily heat production to be 90 Cal. at 32° and 83 Cal. at 38°.

### CALORIGENIC ACTION OF FOOD AT VARIOUS ENVIRONMENTAL TEMPERATURES

In calculating calorigenic action the figures for metabolism at full feed and for fasting katabolism were used. Since it was impossible to obtain data on the fasting katabolism of birds raised at 16° and 18° C., the heat increment was calculated only for birds raised at environmental temperatures of 21°, 35°, and 38°. These data are given in table 8.

TABLE 8.—*Calorigenic action of food of chicks kept at different environmental temperatures*

| Item | Data for indicated environmental temperatures | | |
|---|---|---|---|
| | 21° C. | 35° C. | 38° C. |
| Daily basal heat production per $kg^{3/4}$ calculated to the age of 10 days ..... Calories | 149 | 92 | 82 |
| Daily heat production at full feed per $kg^{3/4}$ ..... do | 235 | 168 | 121 |
| Daily heat increment at full feed per $kg^{3/4}$ ..... do | 86 | 76 | 39 |
| Daily available energy in food per $kg^{3/4}$ ..... do | 315 | 238 | 195 |
| Heat increment per 100 Cal. available energy at full feed ..... percent | 27 | 32 | 20 |

Since the average age at full feed was 10 days, and the age at which the fasting katabolism was determined was 16 days, it was necessary to calculate a theoretical fasting katabolism for the age of 10 days.

The fact that the metabolism at full feed bears a close relationship to the energy value of food consumed, and the observation of Kleiber (*10*) that for very different animals the total energy intake seems to be approximately equal to the same multiple of the fasting katabolism, make possible the calculation of the calorigenic action. It is assumed that the fasting katabolism of the birds, during the period studied, increased by 1 percent of the mean for each additional day of age as determined for the metabolism at full feed.

The following equation was used to calculate a theoretical fasting katabolism for chicks 10 days old (*11*): [9]

$$B_{10}\times(1+0.01\times 6)=B_{16}$$

where

$B_{10}$=fasting katabolism per kg$^{\frac{3}{4}}$ at the age of 10 days

$B_{16}$=fasting katabolism per kg$^{\frac{3}{4}}$ at the age of 16 days.

### EFFICIENCY OF ENERGY TRANSFORMATION AT VARIOUS TEMPERATURES

The terms "partial efficiency" and "total efficiency" are employed in the same sense as they are used by Kleiber and Dougherty (*11*). The "partial efficiency" can be represented as a quotient obtained by dividing the figure representing an increment of net energy by that for the energy intake necessary to produce the increment of net energy.

$$p=\frac{\Delta A}{\Delta U}$$

$p$=partial efficiency

where

$\Delta A$=change in net energy

$\Delta U$=corresponding change in energy intake

In this equation $\Delta A$ may mean an increase in energy in the animal's body when a trial is carried out above the maintenance level, or it may mean a decrease in the loss of energy resulting from an increase of food consumption in the case of a trial carried out below the maintenance level. Its value is positive in either case. The increase of net energy has been calculated as the difference between the amount of available food energy taken in and the corresponding heat increment (availability is defined on page 534). Thus the partial efficiency at three environmental temperatures has been calculated from the data in table 8. The partial efficiency, in terms of net energy per 100 Cal. of available food energy is, for temperatures of 21°, 35°, and 38° C., 73, 68, and 80 Cal., respectively. Since it was impossible to obtain data on the basal metabolism of chicks at air temperatures of 16° and 18° the partial efficiency for these groups cannot be given. As will be noticed in table 8, there is a considerable difference in the heat increment at 35° and 38°, a discrepancy for which no explanation is now available.

[9] Experiments are under way from which it is hoped to measure this relation of age to basal metabolism. It is seen from the equation above that the correction for age for the present trials amounts to 6 percent of the fasting katabolism. Even if the coefficients of age were actually considerably different from that assumed (1 percent) the total correction would not seriously affect the conclusions reported here.

The term "total efficiency" as used here refers to the net energy expressed as percentage of the available food energy. The total efficiency and the partial efficiency are related (*11*), as is shown by the following equation.

$$\eta_t = \frac{A}{U} = \frac{\eta_p (U-E)}{U} = \eta_p \left(1 - \frac{E}{U}\right)$$

where

$\eta_t$ = total efficiency
$\eta_p$ = partial efficiency
$U$ = energy of food intake
$E$ = energy derived from food for maintenance
$A$ = net energy in production

The total efficiency would approach the partial efficiency if a very small proportion of the total food energy were required for maintenance, and it equals zero when the energy necessary for maintenance becomes equal to total food energy taken in.

Fasting heat production data have been used in calculating the partial efficiency, but they are not necessary for calculating the total efficiency; therefore the figures for total efficiency cannot have been influenced by possible errors which might be present in the measurement of partial efficiency such as the effect of social temperature regulation on the fasting heat production. The total efficiency calculated from data in table 6 is presented in table 9. The lowest total efficiency was found at 18° C., while the total efficiency at 16° was higher than that at 18° but not so high as that at 21° during the first 8 days of trial. Through an experimental period of 8 days the greatest total efficiency was found at 35° and 38° (36 percent).

TABLE 9.—*Total efficiency of energy utilization in growing chicks kept at different temperatures while 5 to 12 and 5 to 15 days old*

| Item | Total efficiency for indicated environmental temperature and age of chicks | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 16° C. | 18° C. | 21° C. | | 35° C. | | 38° C. | |
| | 5–12 days | 5–12 days | 5–12 days | 5–15 days | 5–12 days | 5–15 days | 5–12 days | 5–15 days |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Energy in gained body substance ×100 / Available food energy | 20 | 15 | 23 | 25 | 36 | 29 | 36 | 38 |

## SUMMARY

White Leghorn chicks were raised at environmental temperatures of 16°, 18°, 21°, 35°, and 38° C. from 5 to 14, 15 or 16 days of age, inclusive. Groups of five chicks were kept at controlled air temperatures and were matched by groups of 10 chicks kept in a conventional brooder. Both the control and the experimental groups had free access to feed which was considered qualitatively complete. The respiratory exchange of the chicks kept at controlled air temperatures was measured, and the fasting katabolism was determined. Food

consumed and excreta were weighed and were analyzed for nitrogen, carbon, and energy content.

No deaths occurred among the chicks kept at 21° C. or above, nor among the control birds. Of five chicks kept at 18° two had died by the end of the tenth day of the experiment, and of the same number kept at 16° three had died.

Post-mortem examination of the birds lost at 16° and 18° C. disclosed no observable abnormalities of the internal organs, but in each the alimentary tract was entirely filled with food.

The mean growth rate of the control birds was $4.4 \pm 0.3$ g per day, while that of the experimental chicks ranged from $2.2 \pm 0.4$ g at 16° C. to $4.5 \pm 0.3$ g at 35° during the first 8 days of the experiment.

Food consumed was approximately a linear negative function of the environmental temperature.

Availability of food, or $\frac{\text{food} - \text{excreta}}{\text{food}} \times 100$, was somewhat the greater at higher temperatures than at 16° and 18° C.

The $CO_2$ production reached a maximum at 18° C., and decreased as environmental temperature increased. $CO_2$ production per $kg^{.75}$ (0.75 power of body weight expressed in kilograms) was less at 16° than at 18°.

Energy of body substance gained per day exhibited a minimum of 45.7 Cal. per $kg^{.75}$ at 18° C., and a maximum of 88.3 Cal. per $kg^{.75}$ at 35° during the first 8 days of the experiment. At 16°, 63.5 Cal. of net energy was stored as gain in body substance per $kg^{.75}$ per day.

The environmental temperature had a pronounced effect on the composition of body substance gained. The amount of fat stored per gram of increase in body weight was greatest at 35° and 38° C. At 18° no fat was stored, while at 16° fat storage was exceeded only by that at 35° and 38° during the first 8 days of the experiment. The gain of protein per gram increase in body weight was greatest at the lowest environmental temperature. The absolute increase in protein at 16° was exceeded at all the higher temperatures except 38°. The gain in protein varied from 0.224 g (38°) to 0.375 g (16°) per gram of increase in body weight. Maximum energy content per gram of weight gained was 3.24 Cal. at 16°, and the minimum per gram of weight gained was 1.35 Cal. at 18°. The minimum amount of water (0.509 g per gram increase in body weight) was stored at 16°; the maximum (0.762 g per gram increase in body weight) was stored at 18°.

The following fasting katabolic rates were determined: 158 Cal. per $kg^{.75}$ per day at 21° C., 98 Cal. per $kg^{.75}$ per day at 35°, and 87 Cal. per $kg^{.75}$ per day at 38°.

The partial efficiency, or the increase in net energy per unit of the corresponding increase in food energy, was determined for environmental temperatures of 21°, 35°, and 38° C.

At 35° and 38° C. total efficiency, or total energy in the produced body substance expressed as percentage of the available food energy taken in, was 36 percent during the first 8 days of the experiment, while at 21° total net energy was 23 percent of the available energy. At 18° net energy was 15 percent of the available energy, and at 16° it was 20 percent.

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# SOME PHYSIOLOGICAL STUDIES OF CROWN GALL AND CONTIGUOUS TISSUE [1]

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## INTRODUCTION

As part of an investigation of the pathological plant growth induced by the crown gall organism it appeared desirable to study the nature and physiology of both diseased and contiguous tissue. Only a few comparisons of such tissues have been reported. Strohmer and Stift (*31*) [3] found that the galls of sugar beets were higher in ash, protein, and moisture but lower in sugar than the normal roots. Townsend (*34*) and others found that the galled beets were decidedly lower in sucrose than the normal ones. Klein and Keyssner (*15*) have made an extensive study of the forms of nitrogen found in galls and contiguous tissue of several hosts. In most instances the percentage of the various forms of nitrogen was higher in the galls than in the contiguous stems. Sylwester and Countryman (*32*) found both callus and gall tissue of apple to contain cellulose, pectin, lignin, and gum. The gall tissue also contained tannin, but the callus tissue did not. Berthelot and Amoureux (*4*) found similar differences in tannin content between galls and normal tissue of sugar beets. They (*3*) also compared gall tissues resulting from inoculation of sugar beets with two strains of *Phytomonas tumefaciens* (Smith and Town.) Bergey et al., but obtained no significant differences.

Glutathione and ascorbic acid have been considered to play an important role in the growth of plants. Hammett (*12*) in particular has emphasized the importance of glutathione. Through its constituent amino acids glutathione probably accelerates cell proliferation and protein reconstitution and differentiation. Virtanen (*36*) reported large increases in dry weight of plants grown in sterile nutrient solutions containing ascorbic acid. Binet and Magrou (*6*) and Berthelot and Amoureux (*4*) reported greater amounts of glutathione in crown gall than in the host plant. The latter investigators likewise found nearly twice as much ascorbic acid in the galls as in the beet root.

Several investigators have suggested a relation between the activities of oxidative enzymes and atypical growth. For example, Bristol (*7*) attributed cell stimulation to the unchecked action of locally concentrated, intercellular oxidizing enzymes. A disproportionate balance between the enzymes, especially an overabundance of peroxidase, he

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[3] Italic numbers in parentheses refer to Literature Cited, p. 553.

postulated, would result in hyperoxidation in the epithelial cells. Klein and Ziese (*16*) found the catalase activity in crown gall of beets to be greatly increased over that in healthy beets. Likewise (*17*) an increase in peroxidase in crown gall of horseradish paralleled the increase in catalase. The activity of diseased tissue was 80 to 100 percent greater than that of healthy tissue. Smith (*28*, *29*) and Robinson (*25*) were of the opinion that atypical growth may be caused by uncontrolled respiration but that the initial cell stimulation was caused by an "oxygen-hunger." In view of the strongly aerobic nature of *Phytomonas tumefaciens* (*26*), the oxygen may be greatly reduced in the intercellular spaces, thus modifying the enzyme relation and creating an environment for cell stimulation. According to Kluyver (*18*, *p. 529*), "* * * the conversion of a normal tissue cell into a cancer cell could ultimately depend on a quantitative change in property of one single catalytic agent which determines metabolism." In view of the importance of oxidative enzymes in cell metabolism it seemed desirable to compare the catalase, peroxidase, and oxidase content of normal and crown gall tissue of plants. A preliminary report on part of the work has already appeared (*21*). For a background to this work proximate and other analyses were also made.

## EXPERIMENTAL WORK

Three kinds of plants were used to furnish material for analysis. Tomato (*Lycopersicum esculentum* Mill.) plants were grown in the greenhouse in the late fall and early winter of 1933 and in the field during the summers of 1934 and 1936. When the plants were 6 weeks old, a number of inoculations were made in the upper internodes with the crown gall organism, *Phytomonas tumefaciens*. A sufficient amount of gall tissue for analysis was produced in 6 weeks after inoculation. Simultaneously with the collection of the galls, sections of the stem immediately above and below the galls were taken to furnish samples of contiguous tissue. The samples from the greenhouse plants were placed in hot alcohol and stored until the following summer before being analyzed. Material from the plants grown in the field was analyzed immediately after harvesting.

A second source of material was the gall and normal tissue of sugar beets (*Beta vulgaris* L.) grown in the field and inoculated in the usual manner. A third source was the naturally occurring galls and contiguous bark from the roots of red raspberry (*Rubus strigosus* Michx.). The sugar-beet and raspberry samples were also analyzed immediately after harvesting. For this purpose 250-g samples were completely extracted with successive portions of hot 60-percent alcohol. The extracted residue was dried and ground to insure uniform sampling. It was employed for determinations of starch, pentosan, and uronic acid. The alcoholic extract was evaporated under reduced pressure to remove the alcohol, diluted with water to a definite volume, and then analyzed for sugar and for alpha amino, amide, ammonia, and nitrate nitrogen. Another portion of fresh tissue was dried at 100° C. for the determination of moisture, ash, ether extract, cellulose, and total nitrogen.

### PROXIMATE AND OTHER ANALYSES

Analyses were made on the dried materials and solutions as follows: Ash, ether extract, total nitrogen, and pentosans by A. O. A. C. methods (*1*); ammonia, amide, and nitrate nitrogen by the method of Sessions and Shive (*27*); cellulose according to Kürschner and Hanak (*19*); starch by the method of Davis and Daish (*8*); uronic acid by the method of Dickson, Otterson, and Link (*10*); alpha amino nitrogen by the method of Van Slyke (*35*); and sugars according to Stiles, Peterson, and Fred (*30*). The results of the analyses are given in tables 1 and 2. Although considerable variability appears, there are certain conspicuous differences between crown gall, which grossly resembles embryonic tissue, and contiguous tissue. These differences are considered in the discussion.

TABLE 1.—*Chemical composition of normal stem and of gall tissues of tomato*

| Analyses | Greenhouse material, 1933 | | Field material, 1934 | | Field [1] material, 1936 | |
|---|---|---|---|---|---|---|
| | Stems | Galls | Stems | Galls | Stems | Galls |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Dry matter | 10.4 | 10.3 | 14.0 | 11.4 | 16.8 | 10.1 |
| Analyses on basis of dry matter: | | | | | | |
| Ash | 12.3 | 13.2 | 7.7 | 14.1 | 8.4 | 14.2 |
| Ether extract | 2.0 | 1.7 | 1.1 | 1.7 | 1.7 | 2.2 |
| Total nitrogen | 3.0 | 3.3 | 2.8 | 4.9 | 1.4 | 3.5 |
| Alpha amino nitrogen | .1 | .23 | .40 | .50 | .25 | .33 |
| Amide nitrogen | | | .35 | .26 | .10 | .08 |
| Ammonia nitrogen | | | .15 | .15 | .06 | .10 |
| Nitrate nitrogen | | | .35 | .24 | .07 | .12 |
| Reducing sugars | 4.5 | 1.9 | 4.6 | 2.3 | 3.9 | 5.1 |
| Nonreducing sugars | 3.0 | 2.3 | .35 | 1.1 | 2.0 | 4.7 |
| Starch | 6.8 | 5.0 | 3.3 | 2.3 | 2.7 | 4.3 |
| Cellulose | 30.0 | 22.8 | 31.0 | 15.9 | 35.1 | 20.5 |
| Pentosans | 4.1 | 2.1 | 13.5 | 7.8 | 21.5 | 13.4 |
| Uronic acids | 8.9 | 10.9 | 10.4 | 9.1 | 3.7 | 13.4 |

[1] Produced during July and August 1936.

TABLE 2.—*Chemical composition of normal and of gall tissue of raspberry and sugar beets*

| Analyses | Raspberry | | Sugar beets [1] | |
|---|---|---|---|---|
| | Cortical tissue | Galls | Normal tissue | Galls |
| | *Percent* | *Percent* | *Percent* | *Percent* |
| Dry matter | 40.7 | 17.9 | 20.0 | 16.1 |
| Analyses on basis of dry matter: | | | | |
| Ash | 4.9 | 6.9 | 2.7 | 6.5 |
| Ether extract | 1.6 | 4.1 | .4 | 1.0 |
| Total nitrogen | 1.4 | 3.1 | .86 | 2.88 |
| Alpha amino nitrogen | .33 | .36 | .2 | .31 |
| Amide nitrogen | .02 | .05 | .02 | Trace |
| Ammonia nitrogen | .03 | .23 | .02 | .02 |
| Nitrate nitrogen | Trace | .0 | .01 | .03 |
| Reducing sugars | 5.7 | 8.0 | .7 | .8 |
| Nonreducing sugars | 1.9 | .0 | 69.6 | 41.64 |
| Starch | 9.9 | 3.0 | .1 | .2 |
| Cellulose | 13.2 | 13.8 | 5.1 | 9.5 |
| Pentosans | 14.5 | 7.3 | 3.4 | 7.0 |
| Uronic acids | 10.1 | 8.2 | 4.5 | 4.1 |

[1] Produced during August and September 1937.

Glutathione determinations were made on galls, stems, and actively growing tips of tomato plants by the method of Okuda and Ogawa (*23*). This method gives both the oxidized and reduced forms of the sulphydryl group. The data (table 3) show that the tips of greenhouse plants contained much more glutathione than either the galls or stems. The galls from field plants had more than the stems.

Ascorbic acid determinations, also, were made on galls and on the tomato tissues by the method of Bessey and King (*5*). The results are given in table 4. As with glutathione, actively growing tips contained much more ascorbic acid than stems or galls in which relatively little was found.

TABLE 3.—*Glutathione content of crown gall and of contiguous tomato stems*

| Material | Trials | Glutathione per 100 g of dry tissue | | Material | Trials | Glutathione per 100 g of dry tissue | |
|---|---|---|---|---|---|---|---|
| | | Reduced form | Oxidized form | | | Reduced form | Oxidized form |
| Grown in the greenhouse: | *Number* | *Milligrams* | *Milligrams* | Grown in the field: | *Number* | *Milligrams* | *Milligrams* |
| Galls | 8 | 1.6 | 1.6 | Galls | 10 | 5.0 | 5.5 |
| Stems | 7 | 1.1 | 1.4 | Stems | 8 | 2.9 | 2.0 |
| Active growing tips | 4 | 7.5 | 3.7 | | | | |

TABLE 4.—*Ascorbic acid content of crown gall and of contiguous tomato tissue*

| Material | Trials | Ascorbic acid per 100 g of dry tissue | Material | Trials | Ascorbic acid per 100 g of dry tissue |
|---|---|---|---|---|---|
| Grown in the greenhouse: | *Number* | *Milligrams* | Grown in the field: | *Number* | *Milligrams* |
| Young galls | 3 | 0.7 | Galls | 12 | .1 |
| Old galls | 3 | .8 | Stems | 12 | .6 |
| Young stems | 3 | .3 | | | |
| Old stems | 3 | .6 | | | |
| Active growing tips | 3 | 2.2 | | | |

## CATALASE

Catalase activity was determined by means of Appleman's apparatus as modified by Davis (*9*). The method involves the measurement in a gas burette of the oxygen liberated from hydrogen peroxide by the enzyme. Two-gram and 10-g samples of gall and contiguous stem tissue, respectively, were ground with a small amount of water, an excess of calcium carbonate, and a small amount of sand. After 2 minutes of grinding the macerated tissue was put through a fine wire gauze, thoroughly washed, and made up to 100 ml. Two milliliters of the gall extract and 10 ml of the stem extract were placed in flasks containing 10 ml of phosphate buffer (pH 7.0) and the flasks attached to a mechanical shaker in a 25° C. constant-temperature bath. When the contents of the flasks reached the desired temperature, 5 ml of 3-percent neutral hydrogen peroxide was added to the flasks, the shaker was started, and the volume of the evolved gas was measured in a gas burette at regular intervals. The readings were converted to standard pressures and temperatures. The galls liberated 160 percent more gas than the same weight of

contiguous stem tissue. The data in figure 1 are based on the average of 14 determinations on galls and an equal number of corresponding stems.

PEROXIDASE

Peroxidase activity was determined according to the method of Guthrie (*11*), based on the formation by the enzyme of phenol indophenol from *p*-phenylenediamine hydrochloride and alpha-naphthol, in the presence of hydrogen peroxide. One milliliter of a 10-percent plant extract prepared by grinding 10 g of tissue and diluting to 100 ml was used for each determination. As seen from figure 2, the galls were approximately 120 percent more active in the formation of indophenol than an equal weight of the contiguous stem. The data

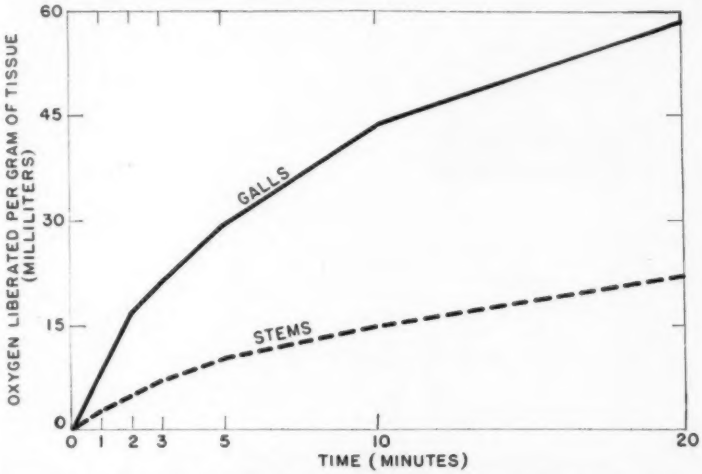


FIGURE 1.—Catalase activity of crown gall and of contiguous stem tissue of tomato.

are based on the average of 19 determinations on galls and an equal number of corresponding stems.

OXIDASE

Oxidase activity was measured by the Bunzel apparatus as modified by Harvey (*13*), based on the absorption of oxygen by pyrogallol. Twelve milliliters of a 1-percent solution of pyrogallol was placed in the larger of the two arms of the apparatus, and in the other, 5 ml of gall or stem juice together with 1 ml of phosphate buffer (pH 6.5). In the vial was placed 1 ml of concentrated sodium hydroxide. The apparatus was immersed in a 25° C. constant-temperature bath and agitated for 2 hours by means of a mechanical shaker. The amount of oxygen absorbed was measured by the difference in the mercury column. The galls showed approximately 130 percent more oxidase activity than the contiguous stem (fig. 3). The data are based on the average of nine determinations on galls and an equal number of corresponding stems.

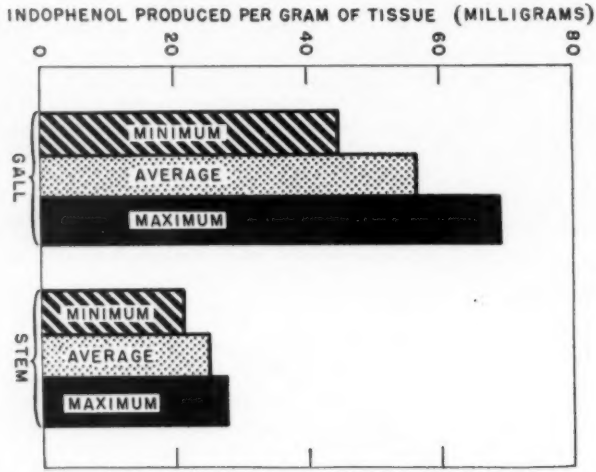


FIGURE 2.—Peroxidase activity of crown gall and of contiguous stem tissue of tomato.

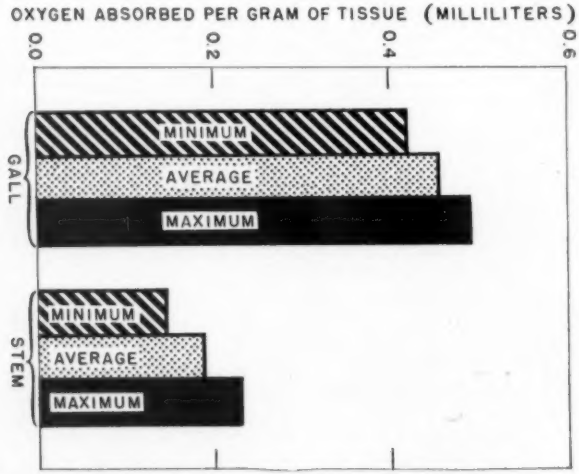


FIGURE 3.—Oxidase activity of crown gall and of contiguous stem tissue of tomato.

### TYROSINASE

The activity of tyrosinase was determined by a modified method of Raper and Wormall (*24*), which involves the estimation of the unchanged tyrosine by means of phenol reagent at various intervals. Fifty milliliters of expressed crown gall juice were placed in a 500-ml flask containing 200 ml of 0.05-percent tyrosine solution buffered with borate to pH 8.0. The flasks were immersed in a 25° C. constant-temperature bath and rapidly aerated. At regular intervals 10-ml samples were withdrawn and pipetted into 0.5 ml of 10-percent acetic acid and the mixture was brought to boiling. The solution was filtered into 100-ml volumetric flasks and the precipitate washed well with hot water. The filtrate was diluted to about 50 ml; 5 ml

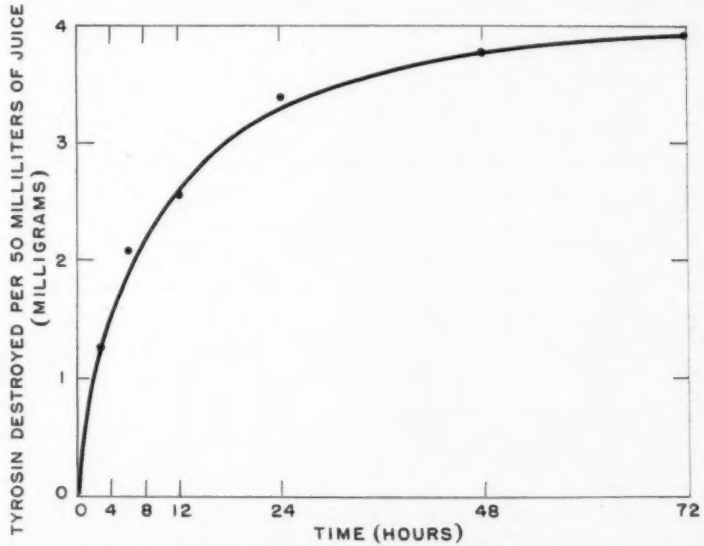


FIGURE 4.—The rate of destruction of tyrosine by the tyrosinase of crown gall from tomato.

of phenol reagent and 25 ml of saturated sodium carbonate were added. After standing for one-half hour the flasks were made up to 100 ml and compared colorimetrically with a standard containing 1 to 4 mg of tyrosine in 100 ml prepared at the same time as the unknown. In 8 hours 50 ml of crown gall juice destroyed one-half of the tyrosine, whereas no loss was detected from a similar preparation of stem tissue (fig. 4). The data are based on the average of six determinations on galls and an equal number of corresponding stems.

### HYDROGEN-ION CONCENTRATION

Hydrogen-ion concentration of galls and of contiguous stem both above and below the galls was determined with a glass electrode. About 3 g of tissue was mascerated in 10 ml of water, and the determinations on the liquid were made within 3 minutes. Nineteen

representative determinations gave the following averages: Gall tissue, pH 5.72; stem tissue pH 5.79. This indicates that no significant difference existed between the tissues, when large masses were thus examined. It is possible, however, that significant differences exist between different portions of a given tissue, as suggested by Berridge (*2*).

## DISCUSSION

The analyses made of the galls and contiguous tissue indicate a condition in the galls similar to that found in young plant tissues. The ash, total nitrogen, and simple forms of nitrogen in tomato are generally higher, whereas nonmetabolically active materials, such as cellulose and pentosans, are lower in the galls than the host plant. The cellulose and pentosans of sugar beets are higher in galls than in contiguous uninfected tissue. The difference between the two tissues in all three host plants is particularly noteworthy with respect to the more highly organized nitrogen. This conclusion is apparent if the sum of the nitrogen fractions is subtracted from the total. The difference in nitrogen thus obtained, probably polypeptide or protein in character, is from two to four times as high in the gall as in normal tissue. So far as the analyses reported are concerned the papers cited in the introduction are in general confirmed by the present studies.

Glutathione is found in greater abundance in the galls than in contiguous stems, but it is even more abundant in the actively growing tips. This situation is in accordance with Hammett's views on the role of glutathione in the organization of protein.

The activity of the oxidizing enzymes may be considered a measure of the metabolic status of the tissue, and hence may serve as an indicator of the physiological response of plants to various treatments. Since the galls are in a highly active vegetative state, it is not surprising to find the concentration of catalase, peroxidase, and oxidase greater in the galls than in the stems. It is doubtful that the increase in catalase is owing to the hydrogen-ion concentration as suggested by Harvey (*13*), since no significant difference was found in the pH value of the galls and neighboring tissue used. Bristol (*6*) and Lantz (*20*) reported an inhibitory action of catalase on the oxidation processes within the cell. Unpublished determinations in the writers' laboratories on the rate of respiration, as measured by the Barcroft apparatus, indicated a great increase in the uptake of oxygen in the galls over that of the contiguous uninoculated tissue. It appears that under these conditions an environment would be created in which there would be an insufficient amount of oxygen for some of the cells. This, according to Smith (*28*), and Smith, Brown, and Townsend (*29*), would compel these cells to divide if they were to live.

The tyrosinase activity of the gall tissue deserves special comment. Although traces of this enzyme were observed both in a culture of *Phytomonas tumefaciens* and in the tomato plant, the tyrosinase of the galls is so great that the amounts cannot be quantitatively compared. Alpha amino nitrogen and tyrosinase activity were, respectively, 20 and 200 percent greater in the galls than in the contiguous stem. Tottingham, Nagy, and Ross (*33*) found a condition similar to this in abnormal potatoes. Rapidity of oxidation, indicated by

the increase in oxidative enzymes, and presence of a large amount of amino acids may favor both production and activity of tyrosinase in the galls. Nobutani (*22*) found a marked stimulation of tyrosinase activity on a *p*-cresol substrate by a number of amino acids.

All of the enzyme determinations are calculated on the basis of whole tissue and, therefore, may not be on a comparable basis. The contiguous tissue contains larger proportions of inert material, such as cellulose and pentosans, than is found in the galls. Since the metabolically active protoplasm is largely composed of nitrogenous material with only a small amount of carbohydrates, the nitrogen content instead of whole tissue may be used as another basis for calculating enzyme activity. But even on the basis of total nitrogen the galls were higher in catalase, oxidase, and peroxidase, by 86, 73, and 57 percent, respectively.[4]

## SUMMARY

A number of analyses have been made on the galls and contiguous tissue from tomatoes, raspberry, and sugar beets. In general the composition of gall tissue resembled that of young plants, being high in nitrogen and low in fibrous material. In sugar beets, however, the galls were more fibrous than the succulent host plant. The composition of the galls and contiguous tissues varied greatly depending upon the time of harvest and the species of plant.

The glutathione content of the tomato galls was greater than that of the contiguous stems, but was much lower than that of the growing tips.

The more metabolically active tissue produced the greater amount of ascorbic acid.

The hydrogen-ion concentration of stems and galls of tomato tissue were approximately the same.

Catalase, oxidase, and peroxidase activity, on the wet-weight basis, were 160, 130, and 120 percent greater, respectively, in the tomato galls than in the contiguous tomato stem tissues. Calculated on the basis of total nitrogen instead of wet weight, the figures for galls were 86, 73, and 57 percent greater, respectively, than those for stems.

Extracts from tomato galls rapidly destroyed tyrosine but a similar preparation from stems showed no tyrosinase activity.

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